CHAPTER 7

HYDROLOGY

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Appendix

7.1 GROUNDWATER HYDROLOGY

7.1.0 SCOPE

Section 7.1 presents discussion of groundwater conditions within and adjacent to the permit area, which consists of lease areas SL 062648 and U 054762 (Figure 7-1). Conclusions drawn herein are based upon a detailed seep and spring survey of the area, limited exploratory drilling, and the results of groundwater investigations conducted by others in the region of the mine.

7.1.1 METHODOLOGY

Seep and spring surveys were conducted on June 6 and 7, 1985 and October 14 and 15, 1985 within an area that extended approximately one mile north, west, and south of the boundaries of the permit area. The study area for the survey was bounded by Huntington Creek on the east, Blind Canyon on the north, and the ridge between Crandall Canyon and Little Bear Canyon on the south. The western extent of the seep and spring survey extended one mile west of the western boundary of the existing permitted area (see Figure 7-1 for study area boundary).

An aerial reconnaissance of the survey area was initially conducted to provide an indication of spring locations and site accessibility. The area was then traversed on foot to allow springs and seepage points to be precisely located, examined, and sampled.

Geologic conditions at all seeps and springs were noted in the field, including lithologic and structural controls and the geologic formation from which the seepage issued. Signs of usage were also noted. The flow rate was visually estimated and (if sufficient water was present) a sample of the water was collected. The temperature of the water issuing from the spring was measured at the site. All samples were subsequently analyzed in the field for pH and specific conductance.

Regional groundwater conditions were determined from a review of available literature. Where appropriate, conclusions drawn from investigations elsewhere in the region were used to determine approximate local conditions.

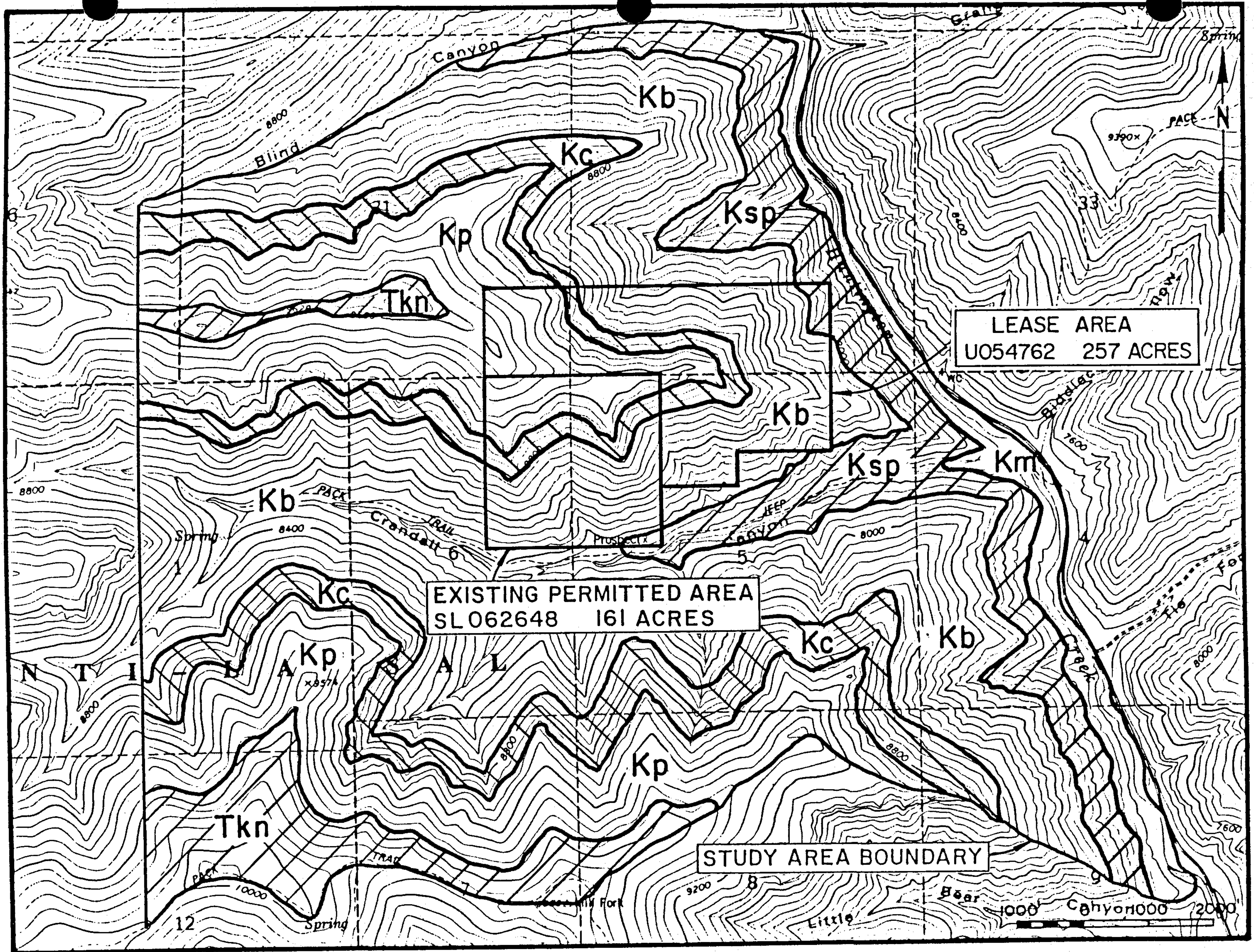

Figure 7-1. Geology of the Crandall Canyon Area (after Doelling, 1972).

7.1.2 EXISTING GROUNDWATER RESOURCES

7.1.2.1 Regional Groundwater Hydrology

Five formations outcrop in the vicinity of lease areas SL 062648 and U 054762 (Figure 7-1). According to Doelling (1972), the Masuk Shale Member of the Mancos Shale (Km on Figure 7-1) is a light gray to blue-gray marine sandy shale in the mine vicinity. This unit is exposed at the mouth of Crandall Canyon and in adjacent areas along Huntington Creek. The Masuk Shale Member yields water locally to seeps and springs but does not serve as a regionally important aquifer (Danielson et al., 1981).

The Star Point Sandstone (Ksp) is predominantly a light-gray massive sandstone with minor interbedded layers of shale and siltstone near its base (Doelling, 1972). In the vicinity of the mine, the Star Point Sandstone is 350 to 450 feet thick. The Star Point serves as an important regional aquifer (Danielson et al., 1981), yielding water to several minor and some major springs where fractured and jointed.

The Blackhawk Formation (Kb) is the principal coal-bearing unit in the region (Doelling, 1972). This formation consists of interbedded layers of sandstone, siltstone, shale, and coal, and reaches a thickness of about 1000 feet in the mine area. The principal coal seam (the Hiawatha seam) is present near the base of the formation. The formation yields water to springs and coal mines when fractured. Where it is locally interbedded with the Star Point Sandstone, the lower portion of the Blackhawk Formation is considered an aquifer (Danielson et al., 1981).

The Price River Formation overlies the Blackhawk Formation and consists of the basal tan to brown cliff-forming Castlegate Sandstone (Kc) and the slope-forming Upper Price River Member (Kpr). Fluvial sandstones of the Castlegate are massive and medium- to coarse-grained. In the area of the mine, the Castlegate is approximately 200 feet thick. The Castlegate yields water locally to seeps and springs but does not serve as an important regional aquifer because it is commonly drained within short distances from its recharge area due to deeply incised canyons (Danielson et al., 1981).

The Upper Price River Member (Kpr) consists predominantly of friable calcareous sandstone interbedded with pebbly conglomerates and shales. It forms steep receding slopes and reaches a maximum thickness of about 600 feet in the mine area (Doelling, 1972). This formation yields water locally to seeps and springs (Danielson et al., 1981). However, like the Castlegate Sandstone, deeply incised canyons in the area prevent the Upper Price River Member from being an important regional aquifer.

The uppermost formation that outcrops within the area adjacent to the mine area is the North Horn Formation (Tkn). This formation consists of interbedded limestones, sandstones, and shales (Doelling, 1972). Due to high topographic presence but limited aerial extent near the mine area, the North Horn Formation in the vicinity of the permitted and proposed lease areas serves primarily as a recharge unit to underlying formations rather than as an important source of water itself.

Investigations by Danielson et al. (1981) indicated that most, if not all, groundwater in the region is derived from snowmelt. Recharge tends to be limited in areas underlain by the Price River Formation and older rocks (relative to recharge in areas underlain by younger rocks) due to slope steepness and relative imperviousness (both of which promote runoff rather than infiltration of snowmelt).

Detailed potentiometric surface data are not available for the region surrounding the permit area. However, the deeply incised canyons interrupt the flow of groundwater in much of the area. Danielson et al. (1981) suggest that groundwater generally moves from high areas of recharge to low areas of drainage, principally along stream channels. This flow pattern is altered locally where geologic structure plays a dominant role.

The predominant chemical constituents in most springs in the region are calcium and bicarbonate (Danielson et al., 1981). Dissolved solids concentrations generally range from about 50 to 750 milligrams per liter. Regionally, the concentrations of major dissolved constituents in water from individual geologic units is highly variable, due to the complex lithologic nature of the area (Danielson et al., 1981).

7.1.2.2 Mine Plan Area Aquifers

Results of the seep and spring inventories conducted in the study area were submitted previously to DOGM (EarthFax Engineering, 1985a, 1985b). Locations of the seeps and springs discovered during the inventories are shown in Figures 7-2 and 7-3. Data collected during the inventories are included in Tables 7-1 and 7-2.

Over 50 percent (43 out of 80) of the seeps and spring discovered during the June 1985 inventory issued from the Blackhawk Formation. However, flow rates at these points were normally minimal (less than one gallon per minute), with seepage issuing predominantly at the interface between sandstone lenses

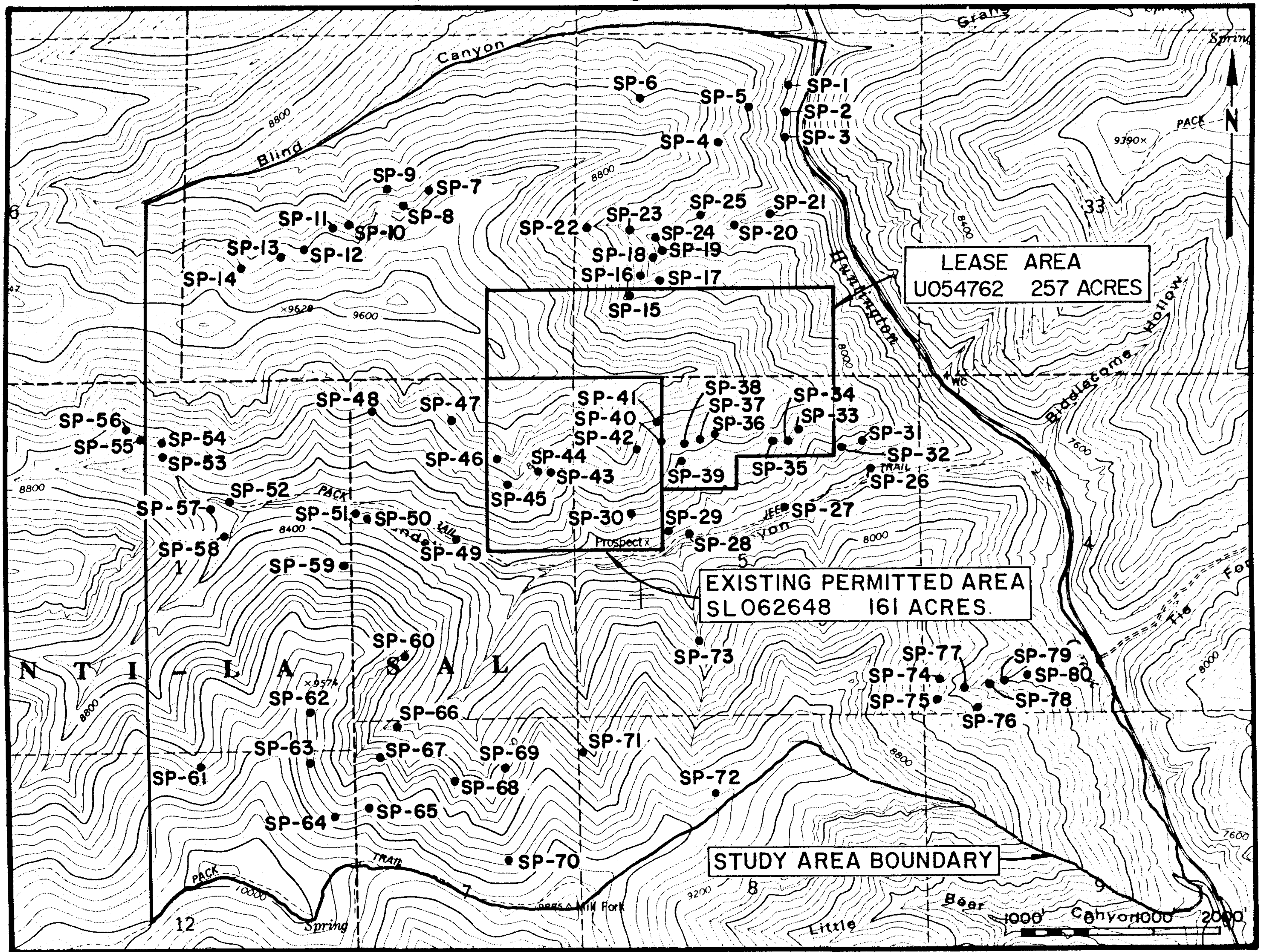

Figure 7-2. Locations of Seeps and Springs from the June 1985 Inventory.

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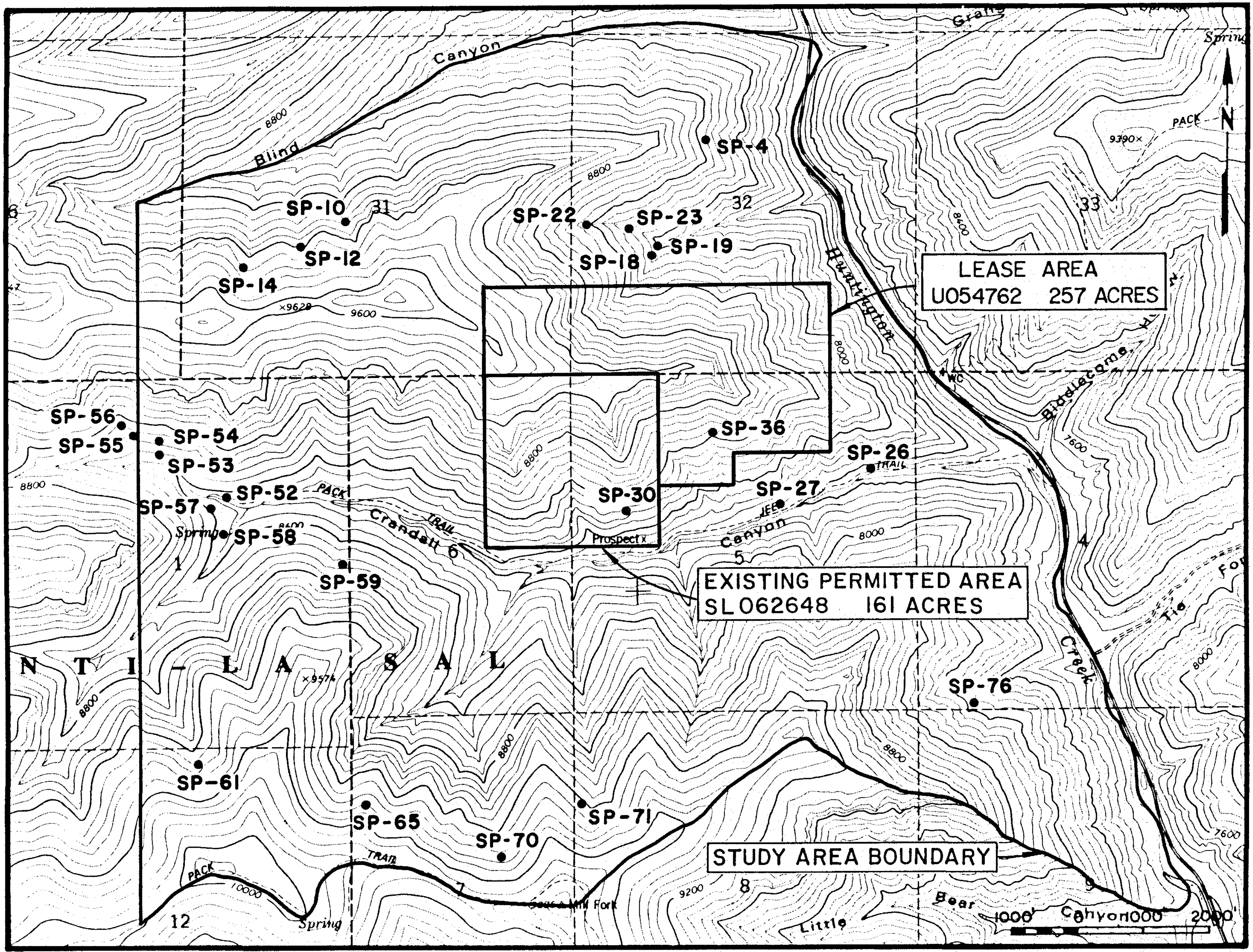

Figure 7-3. Locations of Seeps and Springs from the October 1985 Inventory.

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Table 7-1. Results of June 1985 seep and spring survey.

Field Number	Flow (gpm)	pH (Units)	Specific Cond.[(a)]	Temp (°C)	Geology	Use
SP-1	0	(b)	(b)	(b)	From base of Starpoint SS over Masuk Sh. Member of Mancos Sh.	None
SP-2	0	(b)	(b)	(b)	From base of Starpoint SS over Masuk Sh. Member of Mancos Sh.	None
SP-3	4	8.12	730	17.0	From sandstone bedding plane in Starpoint SS	None
SP-4	6	7.86	660	10.0	From colluvium at head of landslide in Blackhawk Fm.	Signs of Wildlife
SP-5	0	(b)	(b)	(b)	From colluvium over sandstone in Starpoint SS	None
SP-6	5	7.67	590	4.5	From sandstone bedding plane in Blackhawk Fm.	Signs of Wildlife
SP-7	10	8.36	440	10.0	From snow patch at top of Castlegate SS	Signs of Wildlife
SP-8	20	7.95	280	3.5	From snow patch at top of Castlegate SS	Signs of Wildlife
SP-9	0	(b)	(b)	(b)	From sandstone/shale interface Castlegate SS/Blackhawk Fm.	None
SP-10	40	7.90	220	10.0	From snow patch at base of Castlegate SS	Signs of Wildlife

Table 7-1. (Continued).

SP-19 Quarterly Monitoring sites

Field Number	Flow (gpm)	pH (Units)	Specific Cond.(a)	Temp (°C)	Geology	Use
SP-11	0	(b)	(b)	(b)	From colluvium over sandstone of Castlegate SS	None
SP-12	15	7.66	250	3.0	From base of sandstone (Price River Fm.) in channel bottom	Signs of Wildlife
SP-13	3	8.57	100	7.0	From sandstone at head of slide in Price River Fm.	Signs of Wildlife
X SP-14	25	8.10	150	5.5	From fractured sandstone and soil in Price River Fm.	Signs of Wildlife
SP-15	0	(b)	(b)	(b)	From colluvium over sandstone in Blackhawk Fm.	None
SP-16	1	8.34	560	14.5	From sandstone at head of slide in Blackhawk Fm.	Signs of Wildlife
SP-17	2	7.71	460	10.0	From sandstone/shale interface in Blackhawk Fm.	Signs of Wildlife
X SP-18	10	7.42	500	7.0	From sandstone bedding plane in Star Point SS	Signs of Wildlife
SP-19	5	7.60	620	6.5	From sandstone at head of slide in Blackhawk Fm.	None
SP-20	0	(b)	(b)	(b)	From sandstone bedding plane in Star Point SS	None

Table 7-1. (Continued).

Field Number	Flow (gpm)	pH (Units)	Specific Cond.[a]	Temp (°C)	Geology	Use
SP-21	2	8.53	820	13.5	From sandstone bedding plane in Star Point SS	Signs of Wildlife
SP-22	4	8.05	230	3.5	From fractured sandstone over shale in Blackhawk Fm.	None
SP-23	5	8.02	550	6.0	From sandstone/shale interface in Blackhawk Fm.	None
SP-24	2	7.35	790	6.0	From sandstone/shale interface in Blackhawk Fm.	Signs of Wildlife
SP-25	<1	6.80	820	10.0	From sandstone bedding plane in Star Point SS	None
SP-26	0	(b)	(b)	(b)	From road cut, sandstone bedding plane in Star Point SS	None
SP-27	0	(b)	(b)	(b)	From colluvium over sandstone in Star Point SS	None
SP-28	<<1	(b)	(b)	(b)	From road cut, sandstone bedding plane in Star Point SS	None
SP-29	0	(b)	(b)	(b)	From road cut, sandstone bedding plane in Star Point SS	None
SP-30	1	8.10	1060	16.5	From sandstone/shale interface in Blackhawk Fm.	None

Table 7-1. (Continued).

Field Number	Flow (gpm)	pH (Units)	Specific Cond.[a]	Temp (^{o}C)	Geology	Use
SP-31	0	(b)	(b)	(b)	From colluvium over sandstone in Blackhawk Fm.	None
SP-32	0	(b)	(b)	(b)	From colluvium over sandstone in Blackhawk Fm.	None
SP-33	<<1	(b)	(b)	(b)	From alluvium over sandstone in Blackhawk Fm.	None
SP-34	0	(b)	(b)	(b)	From colluvium over sandstone in Blackhawk Fm.	None
SP-35	0	(b)	(b)	(b)	From colluvium over sandstone in Blackhawk Fm.	None
SP-36	2	8.39	890	16.0	From sandstone/shale interface in Blackhawk Fm.	Signs of Wildlife
SP-37	0	(b)	(b)	(b)	From sandstone bedding plane in Blackhawk Fm.	None
SP-38	<1	8.22	1180	9.0	From sandstone/shale interface in Blackhawk Fm.	Signs of Wildlife
SP-39	0	(b)	(b)	(b)	From sandstone bedding plane in Blackhawk Fm.	None
SP-40	0	(b)	(b)	(b)	From sandstone bedding plane in Blackhawk Fm.	None

Table 7-1. (Continued).

Field Number	Flow (gpm)	pH (Units)	Specific Cond.(a)	Temp (°C)	Geology	Use
SP-41	<<1	(b)	(b)	(b)	From colluvium over sandstone in Blackhawk Fm.	None
SP-42	<<1	(b)	(b)	(b)	From colluvium over sandstone in Blackhawk Fm.	Signs of Wildlife
SP-43	0	(b)	(b)	(b)	From colluvium over sandstone in Blackhawk Fm.	None
SP-44	0	(b)	(b)	(b)	From colluvium over sandstone in Blackhawk Fm.	None
SP-45	0	(b)	(b)	(b)	From colluvium over sandstone in Blackhawk Fm.	None
SP-46	0	(b)	(b)	(b)	From sandstone bedding plane in Castlegate SS	None
SP-47	0	(b)	(b)	(b)	From sandstone bedding plane in Castlegate SS	None
SP-48	0	(b)	(b)	(b)	From colluvium over sandstone in Blackhawk Fm.	None
SP-49	0	(b)	(b)	(b)	From sandstone bedding plane in road cut in Blackhawk Fm.	None
SP-50	0	(b)	(b)	(b)	From sandstone/shale interface in slump in Blackhawk Fm.	None

Table 7-1. (Continued).

Field Number	Flow (gpm)	pH (Units)	Specific Cond.(a)	Temp (°C)	Geology	Use
SP-51	0	(b)	(b)	(b)	From sandstone/shale interface in slump in Blackhawk Fm.	None
SP-52	1	7.99	600	12.0	From colluvium over sandstone in Blackhawk Fm., w/ travertine	Signs of Wildlife
SP-53	8	7.31	490	5.5	From fractured sandstone with travertine in Blackhawk Fm.	Signs of Wildlife
SP-54	15	7.35	500	5.5	From fractured sandstone with travertine in Blackhawk Fm.	Signs of Wildlife
SP-55	10	7.36	480	5.5	From fractured sandstone with travertine in Blackhawk Fm.	Signs of Wildlife
SP-56	15	7.61	490	5.5	From fractured sandstone with travertine in Blackhawk Fm.	Signs of Wildlife
SP-57	6	7.35	480	5.5	From fractured sandstone with travertine in Blackhawk Fm.	Signs of Wildlife
SP-58	10	7.40	500	5.0	From fractured sandstone in Blackhawk Fm.	Signs of Wildlife
SP-59	1	7.43	690	7.0	From colluvium over sandstone in Blackhawk Fm.	Signs of Wildlife
SP-60	0	(b)	(b)	(b)	From sandstone bedding plane in Castlegate SS	None

Table 7-1. (Continued).

Field Number	Flow (gpm)	pH (Units)	Specific Cond.[(a)]	Temp (°C)	Geology	Use
SP-61	15	7.36	450	2.0	From fractured sandstone in Price River Fm.	Signs of Wildlife
SP-62	0	(b)	(b)	(b)	From sandstone/shale interface in Price River Fm.	None
SP-63	0	(b)	(b)	(b)	From sandstone/shale interface in Price River Fm.	None
SP-64	10	7.33	440	3.0	From fractured sandstone in Price River Fm.	Signs of Wildlife
SP-65	15	7.43	430	5.0	From colluvium over sandstone in Price River Fm.	Signs of Wildlife
SP-66	0	(b)	(b)	(b)	From sandstone/shale interface in Blackhawk Fm.	None
SP-67	0	(b)	(b)	(b)	From sandstone bedding plane in Castlegate SS	None
SP-68	0	(b)	(b)	(b)	From sandstone bedding plane in Castlegate SS	None
SP-69	0	(b)	(b)	(b)	From sandstone bedding plane in Castlegate SS	None
SP-70	15	7.17	550	3.5	From fractured sandstone in in Price River Fm.	Signs of Wildlife

Table 7-1. (Continued).

Field Number	Flow (gpm)	pH (Units)	Specific Cond.[a]	Temp (^oC)	Geology	Use
SP-71	0	(b)	(b)	(b)	From sandstone bedding plane in Castlegate SS	None
SP-72	<<1	(b)	(b)	(b)	From sandstone/shale interface in Price River Fm.	None
SP-73	0	(b)	(b)	(b)	From sandstone/shale interface in Blackhawk Fm.	None
SP-74	0	(b)	(b)	(b)	From sandstone/shale interface in Blackhawk Fm.	None
SP-75	0	(b)	(b)	(b)	From sandstone/shale interface in Blackhawk Fm.	None
SP-76	1	7.48	960	10.0	From sandstone/shale interface in Blackhawk Fm.	Signs of Wildlife
SP-77	0	(b)	(b)	(b)	From sandstone/shale interface in Blackhawk Fm.	None
SP-78	0	(b)	(b)	(b)	From sandstone bedding plane in Star Point SS	None
SP-79	0	(b)	(b)	(b)	From sandstone bedding plane in Star Point SS	None
SP-80	0	(b)	(b)	(b)	From sandstone bedding plane in Star Point SS	None

(a) In µmhos/cm at 25^oC
(b) Insufficient water to sample

Table 7-2. Results of October 1985 seep and spring inventory.

Field Number	Flow (gpm)	pH (Units)	Specific Cond.[a]	Temp (C)
SP-1	Dry	-	-	-
SP-2	Dry	-	-	-
SP-3	Dry	-	-	-
SP-4	0	(b)	(b)	(b)
SP-5	Dry	-	-	-
SP-6	Dry	-	-	-
SP-7	Dry	-	-	-
SP-8	Dry	-	-	-
SP-9	Dry	-	-	-
SP-10	0	(b)	(b)	(b)
SP-11	Dry	-	-	-
SP-12	0	(b)	(b)	(b)
SP-13	Dry	-	-	-
SP-14	1	7.74	340	6.0
SP-15	Dry	-	-	-
SP-16	Dry	-	-	-
SP-17	Dry	-	-	-
SP-18	2	8.15	450	3.0
SP-19	1	8.27	530	3.5
SP-20	Dry	-	-	-

Table 7-2. (Continued).

Field Number	Flow (gpm)	pH (Units)	Specific Cond.[a]	Temp (C)
SP-21	Dry	-	-	-
SP-22	1	7.32	350	3.5
SP-23	2	8.08	670	3.5
SP-24	Dry	-	-	-
SP-25	Dry	-	-	-
SP-26	0	(b)	(b)	(b)
SP-27	0	(b)	(b)	(b)
SP-28	Dry	-	-	-
SP-29	Dry	-	-	-
SP-30	<1	8.19	1150	4.0
SP-31	Dry	-	-	-
SP-32	Dry	-	-	-
SP-33	Dry	-	-	-
SP-34	Dry	-	-	-
SP-35	Dry	-	-	-
SP-36	1	7.85	950	4.0
SP-37	Dry	-	-	-
SP-38	Dry	-	-	-
SP-39	Dry	-	-	-
SP-40	Dry	-	-	-

Table 7-2. (Continued).

Field Number	Flow (gpm)	pH (Units)	Specific Cond.[a]	Temp (C)
SP-41	Dry	-	-	-
SP-42	Dry	-	-	-
SP-43	Dry	-	-	-
SP-44	Dry	-	-	-
SP-45	Dry	-	-	-
SP-46	Dry	-	-	-
SP-47	Dry	-	-	-
SP-48	Dry	-	-	-
SP-49	Dry	-	-	-
SP-50	Dry	-	-	-
SP-51	Dry	-	-	-
SP-52	1	8.00	540	7.0
SP-53	5	7.95	470	5.0
SP-54	5	8.07	500	5.5
SP-55	10	7.59	530	5.5
SP-56	15	7.90	470	6.5
SP-57	6	7.56	470	4.5
SP-58	5	7.70	500	9.0
SP-59	1	7.86	520	5.0
SP-60	Dry	-	-	-

Table 7-2. (Continued).

Field Number	Flow (gpm)	pH (Units)	Specific Cond.[a]	Temp (C)
SP-61	1	8.16	450	9.0
SP-62	Dry	-	-	-
SP-63	Dry	-	-	-
SP-64	Dry	-	-	-
SP-65	<1	8.18	500	3.5
SP-66	Dry	-	-	-
SP-67	Dry	-	-	-
SP-68	Dry	-	-	-
SP-69	Dry	-	-	-
SP-70	0	(b)	(b)	(b)
SP-71	0	(b)	(b)	(b)
SP-72	Dry	-	-	-
SP-73	Dry	-	-	-
SP-74	Dry	-	-	-
SP-75	Dry	-	-	-
SP-76	1	8.35	850	5.0
SP-77	Dry	-	-	-
SP-78	Dry	-	-	-
SP-79	Dry	-	-	-
SP-80	Dry	-	-	-

(a) In umhos/cm at 25°C
(b) Insufficient water to sample

above and less permeable shale layers below. By the time of the October 1985 survey, 27 of these seeps and springs had dried up (compare Figures 7-2 and 7-3, Tables 7-1 and 7-2). Usage at these points of seepage is minimal, due to the low flow rate and often inaccessibility of the seeps.

The low seepage rates measured in most of the seeps and springs issuing from the Blackhawk Formation are due to the low hydraulic conductivity of the formation in its unfractured state. Laboratory permeability data provided by Lines (1985) from a core sample collected in Section 27, T. 17 S., R. 6 E. (approximately 10 miles south of the existing permitted area) indicate that sandstone units within the Blackhawk Formation have an average horizontal hydraulic conductivity of 1.3×10^{-2} feet per day and an average vertical hydraulic conductivity of 3.8×10^{-3} feet per day. Tested samples of shales and siltstones within the Blackhawk Formation have maximum horizontal and vertical hydraulic conductivities of 1.0×10^{-7} and 1.2×10^{-6} feet per day, respectively (Lines, 1985).

The relatively large hydraulic conductivity of the sandstones of the Blackhawk Formation compared with the siltstones and shales indicates that the finer-grained sediments of the formation serve as barriers to the downward movement of water. In simple terms, as water recharges the Blackhawk Formation (either through snowmelt, rainfall, or subsurface seepage from an adjacent formation), it is permitted to percolate downward within the sandstone beds. However, upon reaching a less-permeable siltstone or shale layer, the water is forced to flow laterally to the surface, issuing at the interface between two units of contrasting hydraulic conductivity.

Notable exceptions to the above generality concerning the Blackhawk Formation are present at a few springs that issue from fractured sandstone within the formation. Examples of this phenomenon are present in the western portion of the survey area (SP-53 through SP-58), where flow rates of up to 15 gallons per minute were measured during both the June and October inventories. Travertine deposits are common at these springs, which suggests that the recharge area for these springs is dominated by limestone (probably the North Horn Formation on the ridges to the north and west). The Blackhawk Formation apparently serves more as a conveyance body rather than a significant source of water to these springs.

Several seeps and springs issue at the site from colluvium overlying sandstone of the Blackhawk Formation and the Castlegate Sandstone. These seeps normally are present in drainage bottoms where shallow subsurface water collects at topographic lows. Nearly all flows from seeps of this type were insignificant in both June and October, suggesting (together with the topographic position) that these seeps are intermittent in nature.

Most seeps and springs issuing within the survey area from the Castlegate and Star Point Sandstones flow from bedding planes within these formations. Flows issuing in this manner were generally low during the June inventory (less than one gallon per minute) and nonexistent during the October inventory. Only occasional usage of these sources was evident (due to inaccessibility and low flow rate).

As noted, flow rates measured during the October survey were generally significantly less than those found during the June survey. In June, a total of 80 seeps or springs were found, 34 of which had sufficient flow to sample (the remaining 46 were seeps that could not be sampled). In October, 55 of the sources originally discovered were dry. An additional 7 sources existed only as seeps, with only 18 of the original sources having sufficient flow to sample.

Generally, sources that had a flow of approximately 5 gallons per minute or less in June were dry or existed as seeps in October. Springs with higher flows in June normally were continuing to flow in October. Notable exceptions were SP-7, SP-8, and SP-10. These "springs" were flowing 10, 20, and 40 gallons per minute, respectively, in June but were dry or existed only as a seep in October. Data presented in Table 7-1 indicate that these sources were issuing from snow patches in June, suggesting that most (if not all) of the flow was coming from snow melt.

As noted in Section 7.1.2.1, the Star Point Sandstone which directly underlies the Hiawatha coal seam serves as an aquifer. This formation is regionally extensive and has been identified as an aquifer from the headwaters of Huntington Canyon (20 miles north of the mine) through the Cottonwood Creek watershed (15 miles south of the mine). It is suspected that the Star Point Sandstone serves as an aquifer throughout the Wasatch Plateau.

During the period of March and April 1987, a monitoring well (MW-1) was installed at the Crandall Canyon Mine in the location indicated in Figure 7-4. This well (which may also serve as a water-supply well for the mine) was drilled using air-rotary methods to a total depth of 375 feet and encountered Star Point Sandstone through its entire depth. The lithology encountered during drilling and the completion of the well is indicated in Figure 7-5.

The driller indicated that the formation was relatively homogenous except in the zone from 290 to 335 feet, where the sandstone became coarser. It is from this zone that the well is producing water, with water first being encountered at a depth of about 315 feet. The static water level approximately one week after completion of the well was at a depth of 186.1 feet below

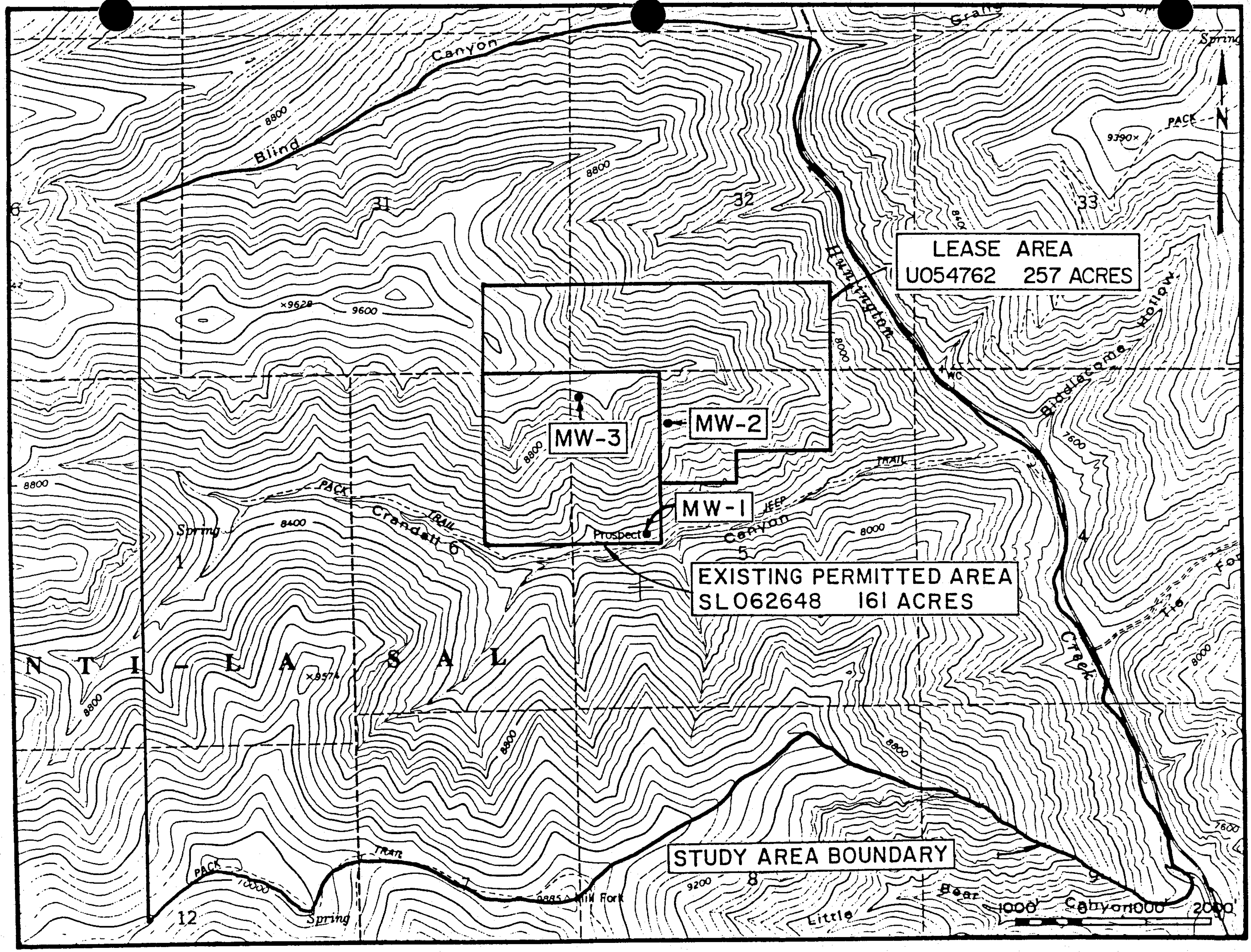

Figure 7-4. Location of Monitoring Wells.

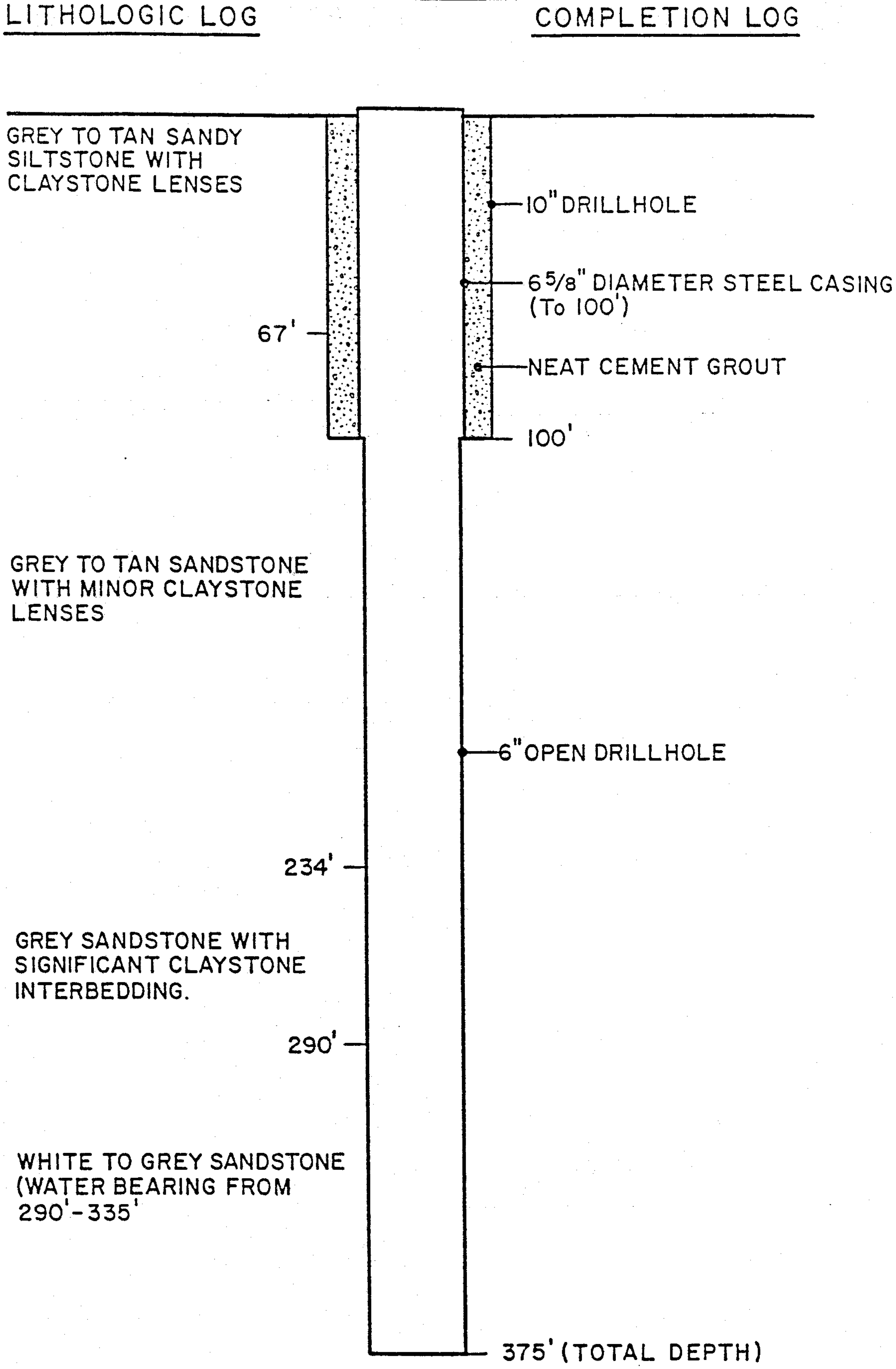

Figure 7-5. Well completion and lithologic log for MW-1.

ground surface, indicating the presence of a significant upward pressure component (approximately 130 feet) within the saturated zone.

After completion of the well, a slug test was performed on the well to determine the approximate hydraulic characteristics of the Star Point Sandstone at the mine site. This test was performed by inserting approximately 10 feet of drill stem below the water surface and allowing the water level to stabilize over a period of 3.75 hours. Although water level recovery was measured during this period, the data are not adequate for slug-test analysis since the drill stem was present within the zone of influence of the injection test, thus displacing additional water during the recovery period.

Following stabilization of the water level, the drill stem was rapidly removed from below the water level and the resulting recovery to static conditions was measured for a period of more than 2 hours. Data collected from this test have been provided to the Division in a letter addressed to Mr. Dave Cline from Richard B. White of EarthFax Engineering, Inc. and dated April 30, 1987. Data collected for the first 700 seconds of the test are provided in Figure 7-6.

The slug test data were analyzed using a method developed by Bouwer and Rice (1976). According to this method,

$$K = \frac{r_c^2 \ln(R_e/r_w)}{2L} \frac{1}{t} \ln \frac{y_o}{y_t} \qquad (7\text{-}1)$$

where K = hydraulic conductivity (feet per day)
r_c = radius of the casing (feet)
r_w = radius of the well
L = length of the screened section (feet)
t = time since test began (seconds)
y_o = maximum drawdown during test or drawdown immediately following slug injection or withdrawal (feet)
y_t = drawdown at time t (feet)

$$\ln(R_e/r_w) = \left[\frac{1.1}{\ln(H/r_w)} + \frac{C}{L/r_w}\right]^{-1}$$

where H = depth from static water level to the base of the producing zone
C = a dimensionless coefficient as a function of L/r_w obtained from Figure 3 of Bower and Rice (1976, p.426)

For the slug test conducted at MW-1,

$r_c = r_w = 0.25$ ft (hole radius of 3 inches)

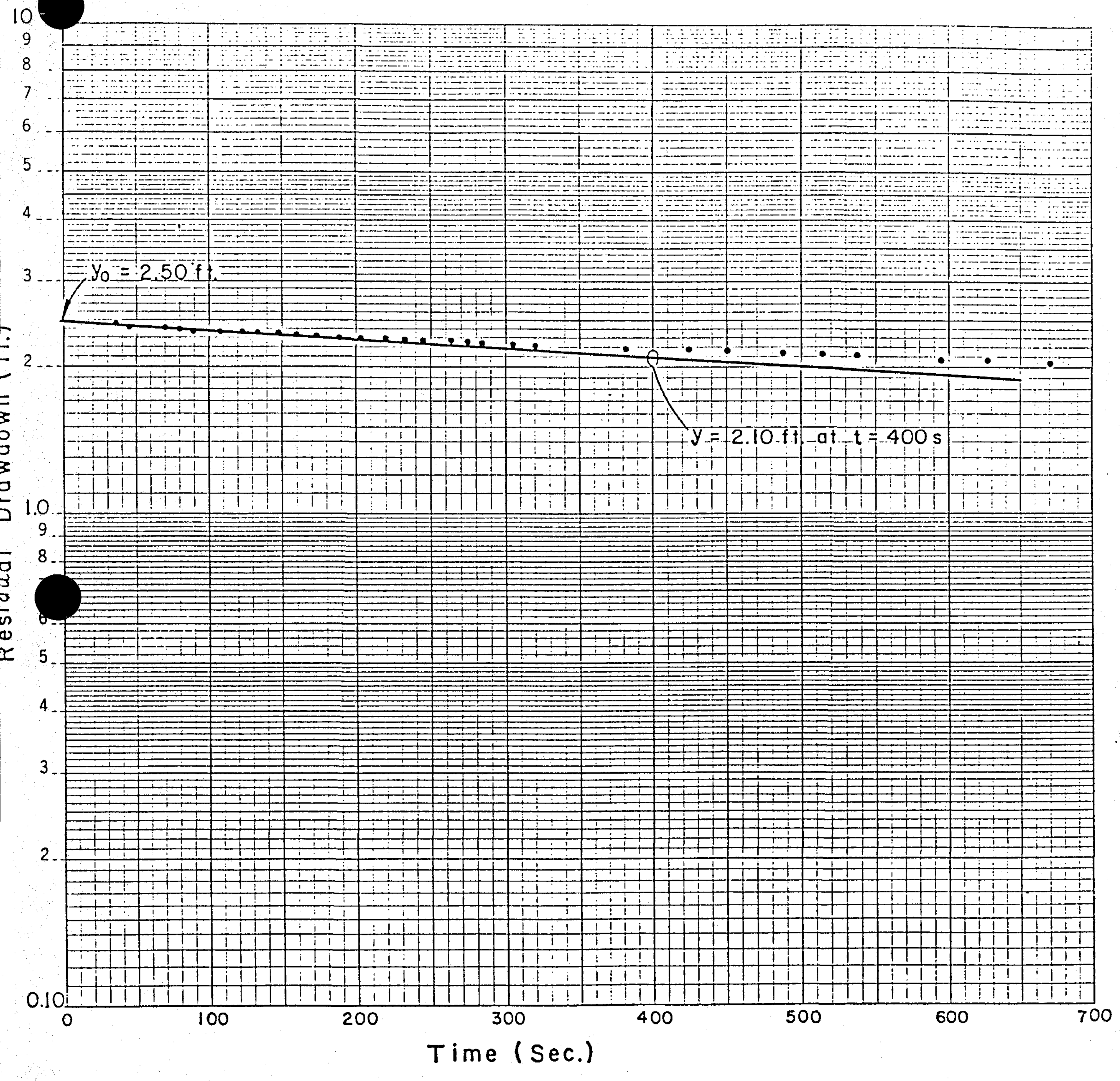

Figure 7-6. Results of slug withdrawal test in MW-1.

L = 335-290 = 45 ft (length of the producing zone according to the driller's records)

H = 335-187 = 148 ft (distance between the static water level and the base of the producing zone

y_o = 2.50 ft (see Figure 7-6)

y_t = 2.10 ft at t = 400 s (see Figure 7-6)

$$\ln(R_e/r_w) = \left[\frac{1.1}{\ln(148/0.25)} + \frac{6.6}{45/0.25}\right]^{-1} = 4.8$$

By means of equation (7-1) and these data, a hydraulic conductivity of 0.1 foot per day was calculated. Assuming that the 45-foot producing zone accounts for the entire thickness of the aquifer at the location of MW-1, this value converts to a transmissivity of 4.5 square feet per day. This transmissivity is similar to those measured by Lines (1985) from pumping tests performed in the Star Point Sandstone near Trail Mountain approximately 10 miles southwest of Crandall Canyon.

Specific information concerning the piezometric surface in the Star Point Sandstone in the mine vicinity is not available due to the general lack of wells in the area and the current presence of only one monitoring well at the mine site. However, qualitative conclusions regarding flow conditions in the Star Point Sandstone in the mine area can be reached from the available data. A plan to collect site-specific data from the Star Point Sandstone is outlined in Section 7.1.6.

According to Danielson et al. (1981), the flow of groundwater in the region is generally from high-elevation recharge areas toward major canyons. If groundwater in the Star Point Sandstone were flowing south toward Crandall Canyon, the water table elevation would be higher than the floor of the mine in areas where the mine floor is at a lower elevation than the canyon bottom (since the floor of the mine rests on top of the Star Point Sandstone). However, inflow to the existing mine workings has been from the roof only, even though the floor of the mine within the western third of the mine area is below the elevation of Crandall Creek. In addition, as noted above, the depth to groundwater at the mouth of the mine (at MW-1) is approximately 186 feet below ground surface. Thus, it is reasonable to assume that groundwater within the Star Point Sandstone beneath the mine does not discharge into Crandall Creek.

Although the regional stratigraphic dip is to the west (see Section 6.4.2), groundwater in the Starpoint Sandstone beneath the mine is assumed to flow eastward from East Mountain to Huntington Canyon rather than westward to Upper Joes Valley. This conclusion is reached based on the following factors:

- The Starpoint Sandstone outcrops in Huntington Canyon and not in Upper Joes Valley. Thus, a natural discharge point is created in Huntington Canyon.

- Huntington Canyon is approximately 800 feet lower in elevation than Little Joes Valley, further enhancing groundwater drainage to the canyon.

- The stratigraphic dip of the Starpoint Sandstone is low (1-3 degrees). Thus, the influence of the dip on groundwater flow can be expected to be minimal.

Hence, the direction of groundwater flow within the Starpoint Sandstone beneath the mine is considered to be predominantly eastward.

In the area of Trail Mountain (located approximately 10 miles southwest of Crandall Canyon) the hydraulic gradient of groundwater in the Star Point Sandstone varies from about 0.11 foot per foot in the recharge area near the ridge line to about 0.03 foot per foot in the discharge area in Straight Canyon (Lines, 1985). Due to the similarity of the geologic conditions in the two areas (Waddell et al., 1981), similar hydraulic gradients are expected in the East Mountain recharge area and Huntington Canyon discharge area, respectively.

Usage of seeps and springs within the survey area is confined entirely to deer, elk, and other wildlife. No signs of use for stock watering or human consumption were noted in either the June or October inventory. As would be expected, wildlife usage of the springs is most abundant where flows are greatest and the source is most accessible.

Data contained in Table 7-1 indicate that the specific conductance of water issuing from springs in June generally increased with increasing stratigraphic depth. This is in agreement with the findings of Danielson et al. (1981). Springs issuing from the Price River Formation typically had a specific conductance during the June survey that varied from 150 to 450 umhos/cm at 25 ^{o}C while those issuing from the Blackhawk Formation and Star Point Sandstone had a specific conductance varying from 500 to 1000 umhos/cm at 25 ^{o}C. This increase in specific conductance is indicative of leaching of minerals by the groundwater as it flows through increasing distances of bedrock to the lower stratigraphic positions.

The pH of water issuing from springs in the survey area showed no trends within or between formations. Values varied from 6.80 to 8.57, averaging 7.74. Hence, spring water in the study area is slightly alkaline.

In those springs with sufficient water to sample, pH generally increased slightly between June and October. Increases normally amounted to 0.1 to 0.5 pH unit. Specific conductance showed no consistent pattern between the June and October data, with approximately as many increases as decreases between June and October.

Water temperatures vary widely at the site. In general, temperatures are lowest in springs issuing from fractures and highest in springs issuing from shallow colluvium over bedrock. Low temperatures generally occurred in springs with relatively low specific conductances.

7.1.3 GROUNDWATER DEVELOPMENT AND MINE DEWATERING

7.1.3.1 Water Supply

As noted previously, none of the seeps or springs inventoried during the June and October 1985 surveys appeared to have been developed for beneficial use. This lack of development includes springs issuing from the Star Point Sandstone. In addition, no water wells other than MW-1 are known to exist within the study area of the spring inventory. Hence, groundwater development has not occurred in the past within the mine plan or adjacent areas other than the drilling of MW-1.

Table 7-3 presents a listing of groundwater rights within the permit and adjacent areas as obtained from the files of the Utah Division of Water Rights in September 1987. More indepth information concerning these rights is contained in Appendix 7-1. Locations of these rights are noted on Figure 7-7.

Although the U.S. Forest Service has obtained rights to certain springs in the area for stock watering (see Table 7-3 and Figure 7-7), these springs did not show signs of current usage for stock watering during the inventory. Additionally, although the Star Point Sandstone serves as an aquifer in the region, groundwater is not obtained therefrom within the mine plan or adjacent areas.

The spring associated with water right 93-1407 was not discovered during the seep and spring inventory. Although it is possible that some seeps were missed during the inventory (due to heavy undergrowth and/or inaccessibility), the potential for missing a major spring is remote. Hence, this source is likely similar to 93-1408 (SP-47), which existed only as a seep.

Table 7-3. Groundwater rights in the mine plan and adjacent areas.

W.U. Claim No.	Owner	Flow (cfs)	Use	Period of Use	Source
93-1407	U.S. Forest Service	.011	Stockwater	June 6 to Aug 25	Spring
93-1408	U.S. Forest Service	.011	Stockwater	June 6 to Aug 25	Spring
93-1409	U.S. Forest Service	.011	Stockwater	June 6 to Aug 25	Spring

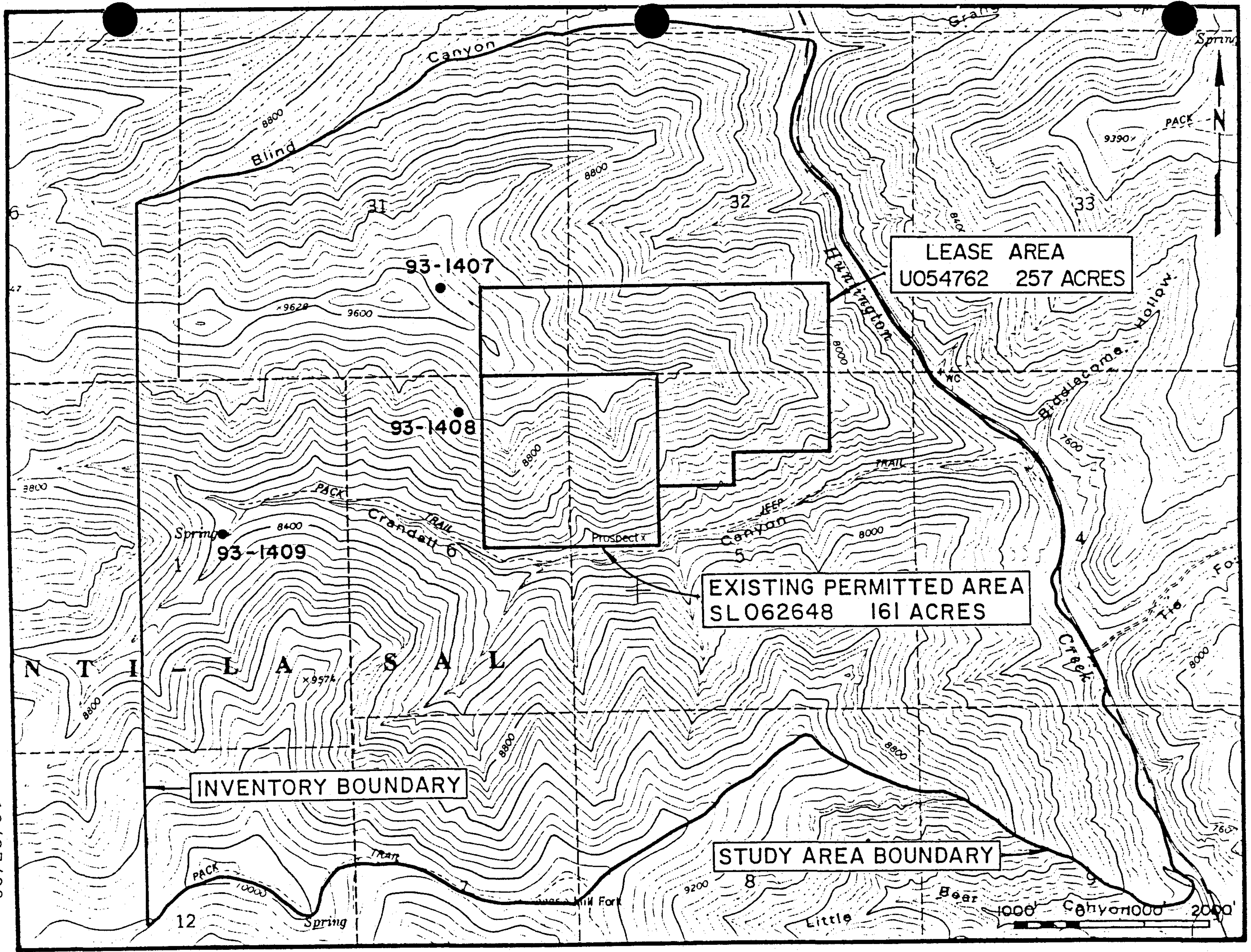

Figure 7-7. Location of Groundwater Rights in the Crandall Canyon Area.

7.1.3.2 Mine Dewatering

Inflow to the existing underground workings amounts to approximately 100 gallons per minute. These inflows originate primarily in gob sections near the working face of the mine. Currently, water encountered in the mine is used underground in the mining process. A modification of the NPDES permit for the sedimentation pond has been obtained to cover discharges from the mine if amounts encountered therein exceed the requirements for under ground use. Although this potential discharge will be covered by the same permit, the underground water will not be discharged through the pond, but will be discharged at the same outfall.

7.1.4 EFFECTS OF MINING OPERATION ON GROUNDWATER

The primary potential for impacts to the groundwater system will occur as a result of subsidence. To estimate the effects of subsidence on the seeps and springs found during the field inventory, a positive limit angle of 60° from horizontal was assumed. This limit angle is considered conservative for estimating potential subsidence impacts since Dunrud (1976) found positive limit angles that varied from 69° in weak overburden to 75° or more in moderately strong overburden in geologically similar areas in the Book Cliffs mining district, Utah and the Sommerset mining district, Colorado.

Mine plans for lease area SL 062648 indicate that 50 percent extraction will occur throughout the mine, with the exception of barrier pillars at the lease boundaries. The barrier pillar at the south lease boundary has been designed to be sufficiently wide to reduce the chance of subsidence along Crandall Creek, thus limiting subsidence in areas north of the creek (see Chapter 12).

Mine plans for lease tract U 054762 indicate that 60 percent extraction will occur throughout the mine, with the exception of barrier pillars at the lease boundaries and coal outcrop barriers near the northeast and southeast corners of the lease area (see Figure 7-8). The barrier pillars at the east and south lease boundaries have been designed to be sufficiently wide to reduce the chance of subsidence along Huntington and Crandall Creeks. Coal outcrop protection barriers at the northeast and southeast corners of lease area U 054762 are designed to protect escarpments in Huntington and Crandall Canyons, respectively, although minor amounts of subsidence may occur (see Chapter 12).

Using a positive limit angle of 60°, the maximum area of potential subsidence was determined as shown in Figure 7-8. As noted by this figure, 19 seeps and springs were found during the

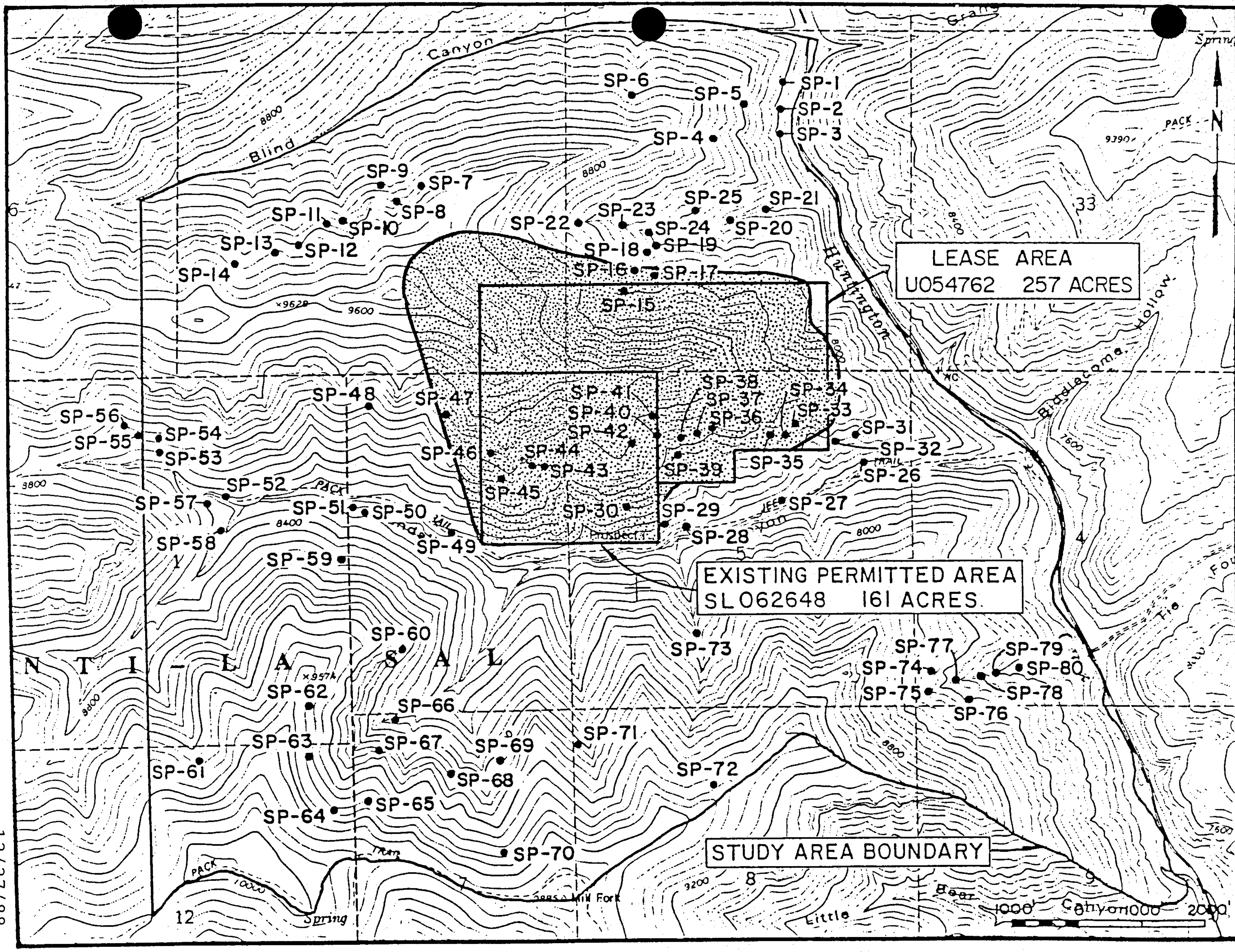

Figure 7-8. Maximum Area of Potential Subsidence.

from the Blackhawk Formation. The two exceptions issue as seeps from bedding planes in the Castlegate Sandstone.

By the time of the October survey, only two springs (SP-30 and SP-36) were found within the area of potential subsidence. All other seeps and springs discovered during the June inventory in the area of potential subsidence were dry during the October survey due to natural seasonal variations in flow.

The maximum flow encountered during the June survey within the area of potential subsidence was one gallon per minute at SP-30 and two gallons per minute at SP-36. Flow at SP-30 occurs as diffuse seepage above the mine portals and is collected in a pipe and routed around the portals to prevent problems at the portal face. There were no signs of usage of this spring during the June inventory. Flow at SP-36 issues form a sandstone-shale contact within the Blackhawk Formation and showed evidence of use by elk and deer.

Deer and elk tracks and droppings were noted in the vicinity of SP-38 and SP-42. Other than these two seeps, no other signs of usage were seen during the June survey within the area of potential subsidence.

Based on this information, subsidence from mining in both lease areas will have minimal impacts on water supplies from seeps and springs in the vicinity of the mine.

Inflows to the mine are insufficient to require dewatering (see Section 7.1.3.2). Hence, impacts due to dewatering are nonexistent.

The water supply for use in the mine is obtained from Crandall Creek. Hence, other than the groundwater encountered within the mine, no groundwater is utilized at the mine for domestic or industrial purposes.

7.1.5 MITIGATION AND CONTROL PLANS

Based on the information presented in Section 7.1.4, subsidence from mining in the Genwal lease area will have minimal impacts on groundwater resources in the vicinity of the mine. Flow rates measured during the June inventory within the area of potential subsidence were minimal, even though the field investigation was conducted shortly after the snow-melt period. Prior to the October survey, all but two sources had dried up. Although it is difficult to determine long-term usage of the springs in the area from one seep and spring inventory, these water sources are of critical value to local wildlife. However the low flow rates encountered at the springs within the area of potential subsidence suggests that these springs produce a minor quantity of water to the local wildlife. If future monitoring efforts indicate that the mine is impacting local springs, a mitigation plan specific to the impact will be developed in consultation with DOGM.

As noted in Section 7.1.3, insufficient inflows are encountered in the existing underground workings to require mine dewatering. If amounts requiring discharge are encountered in the future, a specific plan will be developed in consultation with DOGM to mitigate the impacts of dewatering on the groundwater system.

Should it be necessary to develop alternative water supplies due to unexpected contamination, diminution, or interruption of significant local springs as a direct result of mining activities, the applicant will contact the Division of Wildlife Resources and develop plans to install a guzzler on a case-specific basis. Genwal owns shares in the Huntington-Cleveland Irrigation Company, that can be transfered if required to meet the demands of an alternate water supply.

7.1.6 GROUNDWATER MONITORING PLAN

As noted in Section 7.1.4, only four springs were found during the June 1985 seep and spring survey within the area of potential subsidence with a flow rates of one to two gallons per minute (SP-16, SP-17, SP-30, SP-36). By the time of the October survey, all seeps and springs with the area of potential subsidence except SP-30 and SP-36 had dried up (compare Figures 7-2, 7-3, and 7-8). SP-30 occurs as diffuse seepage from the Blackhawk Formation above the mine portals and is collected in a pipe to avoid problems at the portal face. Flow at SP-36 issues from a sandstone-shale contact within the Blackhawk Formation and showed evidence of use by elk and deer. All major springs (flows of at least five gallons per minute) found during the June 1985 survey were located outside of the area of potential subsidence.

Groundwater monitoring for the Crandall Canyon Mine area will include collection of water quality and quantity data from six springs as well as points of significant inflow to the underground workings. Location of the springs to be included in the groundwater monitoring program are shown on Figure 7-2.

SP-30 and SP-36 will be monitored to determine potential impacts in the immediate vicinity of the mine. SP-30 was chosen because it is the only spring within the area of potential subsidence within lease area SL 062648 that had a flow rate of at least one gallon per minute during the June 1985 inventory. SP-36 was chosen because it issues within the area of potential subsidence within lease area U 054762 and because it had a flow rate during the June 1985 inventory that was of sufficient magnitude (two gallons per minute) to suggest some permanence.

SP-58 will be monitored as an indicator of long-term changes in groundwater issuing from the Blackhawk Formation in an area that will not be affected by mining operations. The magnitude of these changes will be useful when interpreting changes at SP-30 and SP-36.

SP-47 will be monitored since a water right has been filed on this spring by the U.S. Forest Service (see Section 7.1.3.1). Springs SP-19 and SP-22 will be monitored as indications of the water supply in the upper reaches of Blind Canyon.

Four samples will be collected from each of the monitored springs annually. With the exception of SP-30, each spring will be monitored at monthly increments during the accessible portion of the year (generally June through September). These samples will be collected as close as possible to the point of issuance of the springs. Samples will be analyzed according to the list of parameters in Table 7-4. Every fifth year (1990, 1995, etc.),samples collected during the low-flow period of the year (the final sample of the year) will be analyzed according to the list of parameters contained in Table 7-5 (as requested in guidelines from DOGM).

Since SP-30 is collected in a pipe to bypass the portal area, its discharge point is accessible year-round. Hence, this spring will be monitored at the point of pipe discharge quarterly (normally in January, April, July, and October) and analyzed according to Table 7-4. Every fifth year thereafter, the sample collected during the low-flow period (normally October) will be analyzed according to Table 7-5.

All samples will be preserved as soon as practicable after collection. Preservatives to be used will be in accrodance with the most recent U.S. Environmental Protection Agency guidelines. Samples not preserved with a chemical fixative will be placed on ice in an ice chest as soon as possible after collection.

On a quarterly basis (normally in January, April, July, and October), an inventory will be conducted of the active portion of the mine to identify the location and geologic occurrence of mine inflows that exceed three gallons per minute. In consultation with DOGM, certain of these inflows (if they occur) will be selected for continued monitoring. Currently, only one such inflow exists, flowing from the roof of the mine from an exploratory hole (DH-2) that was vertically drilled from within the permit area at the location shown on Plate 6-1. This hole is capped and is allowed to flow only when needed to collect water-quality data.

Table 7-4. Abbreviated groundwater analysis list.

Field Measurements:
Water level or flow
pH
Specific conductance (umhos/cm)
Temperature (^{o}C)
Laboratory Measurements:
Total dissolved solids
Total hardness (as $CaCO_3$)
Bicarbonate (as HCO_3)
Carbonate (as CO_3)
Calcium (as Ca)
Chloride (as Cl)
Dissolved iron (as Fe)
Magnesium (as Mg)
Manganese (as Mn)
Potassium (as K)
Sodium (as Na)
Sulfate (as SO_4)

After selection of the inflow points to be monitored, data will be collected on a quarterly basis and analyzed according to Table 7-4. Every fifth year, samples collected during the low-flow period (normally October) will be analyzed according to Table 7-5.

Genwal is currently applying for a revision to their NPDES permit to cover unexpectedly large inflows of water to the underground workings (i.e., inflows that are greater than can be stored and used underground). The plan developed for this NPDES permit revision will contain information concerning storage, treatment, and monitoring of the water. A copy of this plan and the applicable NPDES permit will be forwarded to DOGM when appropriate.

Water rights apparently have been filed for two additional springs in the area surrounding the lease areas (93-1407 and 93-1408 on Figure 7-7). As noted in Section 7.1.3.1, the source at 93-1407 was not discovered during either of the field inventories and it is surmised that this source exists as a seep only (similar to 93-1408 [SP-47]). Source 93-1408 existed as a seep in June but was dry in October. Hence, it was decided not to monitor these seeps on a long-term basis since they do not flow at a sufficient rate to permit sample collection.
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Genwal has installed one monitoring well (MW-1) near the mine portal in the location indicated on Figure 7-4. Two additional monitoring wells will be drilled underground (see Figure 7-4). MW-2 will be installed in the proposed East Mains near their junction with the North Mains. MW-3 will be installed in the eastern third of Fourth West. These locations were chosen in areas where access will be maintained as lon as possible and still provide as much triangulation with MW-1 as possible.

Each underground monitoring well will be drilled using air-rotary techniques. Each hole will be drilled approximately 2 inches in diameter to a depth of 20 feet bleo the point at which water is first encountered or to a depth of 200 feet, whichever comes first. Drilling of a larger diameter hole at greater depth will be precluded by the inability of a larger drill rig to mobilize underground.

Following drilling, each hole will be surged with air to remove fines that have accumulated in the holes. This surging will continue until the water discharging from the holes is visibly clear. A short section of 2-inch diameter steel surface casing will be driven into the top of the hole and cemented in place. A cap will be placed on this casing to allow closure of each well when not in use.

Construction of the underground monitoring wells will begin during the first quater of 1989. Lithologic and completion logs

Table 7-5. Extended groundwater analysis list.

Field Measurements:

Water level or flow
pH
Specific conductance (umhos/cm)
Temperature (^{o}C)

Laboratory Measurements:

Total dissolved solids
Total hardness (as $CaCO_3$)
Aluminum (as Al)
Arsenic (as As)
Barium (as Ba)

Bicarbonate (as HCO_3)
Boron (as B)
Carbonate (as CO_3)
Cadmium (as Cd)
Calcium (as Ca)

Chloride (as Cl)
Chromium (as Cr)
Copper (as Cu)
Fluoride (as F)
Dissolved iron (as F)

Lead (as Pb)
Magnesium (as Mg)
Manganese (as Mn)
Mercury (as Hg)
Molybdenum (as Mo)

Nickel (as Ni)
Nitrogen-Ammonia (as NH_3)
Nitrite (as NO_2)
Nitrate (as NO_3)
Potassium (as K)

Phosphate (as PO_4)
Selenium (as Se)
Sodium (as Na)
Sulfate (as SO_4)
Sulfide (as S)
Zinc (as Zn)

of the wells will be submitted to DOGM with the results of analyses of the first samples collected from the wells. An interpretation of the hydrogeology of the Star Point aquifer beneath the mine will also be submitted with the initial water-quality results.

Water-level measurements and water-quality samples will be collected from the monitoring wells on a quarterly basis following completion. During the first two years following completion of the in-mine wells and every fifth year thereafter during the operational period of the mine, water-quality samples collected from all wells will be analyzed according to Table 7-5. During interim years, water quality samples will be analyzed according to the list provided in Table 7-4. Monitoring will continue according to this schedule in accessible wells until two years after the completion of surface reclamation activities.

Each monitoring well will be pumped prior to sampling to purge it of stagnant water standing in the hole. In the case of MW-1, purging will be accomplished using a submersible pump. For MW-2 and MW-3, purging will occur using a bladder pump.

In each case, purging will continue until at least 3 times the volume of water standing in the well has been pumped. Samples will be collected directily from the discharge line of the pump. Samples will be preserved and stored in accordance with U.S. Environmental Protection Agency guidelines.

Groundwater monitoring data collected from the area will be submitted to DOGM on a quarterly basis. On an annual basis, a report will be submitted to DOGM summarizing all data collected during the year and containing an analysis of the mine water balance, accounting for mine inflows, outflows, consumptive uses, and sump storage.

Following the completion of mining activities and during the post-mining/reclamation period, water-level and quality samples will be collected annually from the designated springs and MW-1 until the termination of bonding. In-mine wells will be inaccessible following reclamation. Samples will be collected during the latter portion of the summer to represent low-flow conditions. Samples thus collected will be analyzed for the parameters listed in Table 7-4. A report will be submitted to DOGM on a annual basis summarizing the results and assessing mining impacts and system recovery since mining ceased.

7.2 SURFACE WATER HYDROLOGY

7.2.0 SCOPE

Section 7.2 presents a discussion of surface water conditions within and adjacent to the permit area (lease area SL 062648 area U 054762). Conclusions drawn herein are based upon a field reconnaissance of the area and published hydrologic information.

7.2.1 METHODOLOGY

7.2.1.1 General

The U.S. Geological Survey established a gaging station at the mouth of Crandall Creek in 1978. The gaging station was maintained through water year 1984. Data collected from this station were obtained from the Water Resource Division of the USGS in Salt Lake City and used to determine seasonal variations in flows in areas adjacent to the mine plan area. Stream channels crossing the permit area are all ephemeral in nature, with no streamflow data being available.

7.2.1.2 Runoff and Sediment Control

Watershed boundaries used to determine runoff conditions at the site are shown on Plate 7-3. Data obtained from these watersheds were input to a computer code developed by Hawkins and Marshall (1979) to generate runoff hydrographs for the 10-year, 24-hour storm required for designing various facilities. Inflow hydrographs to and outflow hydrographs from the sedimentation pond were developed for the 25-year, 24-hour storm using the hydrology and sedimentology model SEDIMOT II (Warner et al., 1980; Wilson et al., 1980). Both of these codes model runoff using the rainfall-runoff function and triangular unit hydrograph of the U.S. Soil Conservation Service (1972).

According to the U.S. Soil Conservation Service (1972), the algebraic and hydrologic relations between storm rainfall, soil moisture storage, and runoff can be expressed by the equations,

$$Q = \frac{(P-0.2S)^2}{P+0.8S} \qquad (7\text{-}1)$$

and

$$S = \frac{1000}{CN} - 10 \tag{7-2}$$

where Q = direct runoff volume (inches)
S = watershed storage factor (inches)
P = rainfall depth (inches)
CN = runoff curve number (dimensionless).

It should be noted that (a) Equation (7-1) is valid only for $P >= 0.2S$ (otherwise $Q=0$), (b) Equation (7-2), as stated, is in inches, with the values of 1000 and 10 carrying the dimensions of inches, although metric conversions are possible, and (c) CN is only a convenient transformation of S to establish a scale of 0 to 100 and has no intrinsic meaning.

The average curve number for undisturbed areas was obtained from the curves presented in Figure 7-9 using measured cover densities as reported in Chapter 9 of the Permit Application Package for the northern half of lease area SL 062648 (formerly referred to as Tract 2). A curve number of 69 was thus obtained for the undisturbed areas, assuming a hydrologic soil group of C.

The curve number for disturbed and reclaimed areas was chosen from professional judgement and tabulated values presented by the U.S. Soil Conservation Service (1972). Accordingly, a value of 90 was used for the pad and road areas. For reclaimed areas within the disturbed area, a curve number of 75 was assumed.

The translation of the runoff depth to an outflow hydrograph is accomplished in the codes using the triangular unit hydrograph of the U.S. Soil Conservation Service (1972). This unit hydrograph is shown in Figure 7-10 along with a typical curvilinear hydrograph. It is characterized by its time to peak (T_p), recession time (T_r), time of base (T_b), and the relations between these parameters (i.e., $T_r=1.67T_p$; $T_b=2.67T_p$). Thus, from the geometry of a triangle, the incremental runoff (Q) can be defined by the equation,

$$Q = \frac{(2.67T_p)(q_p)}{2} \tag{7-3}$$

or

$$q_p = \frac{0.75 \quad Q}{T_p} \tag{7-4}$$

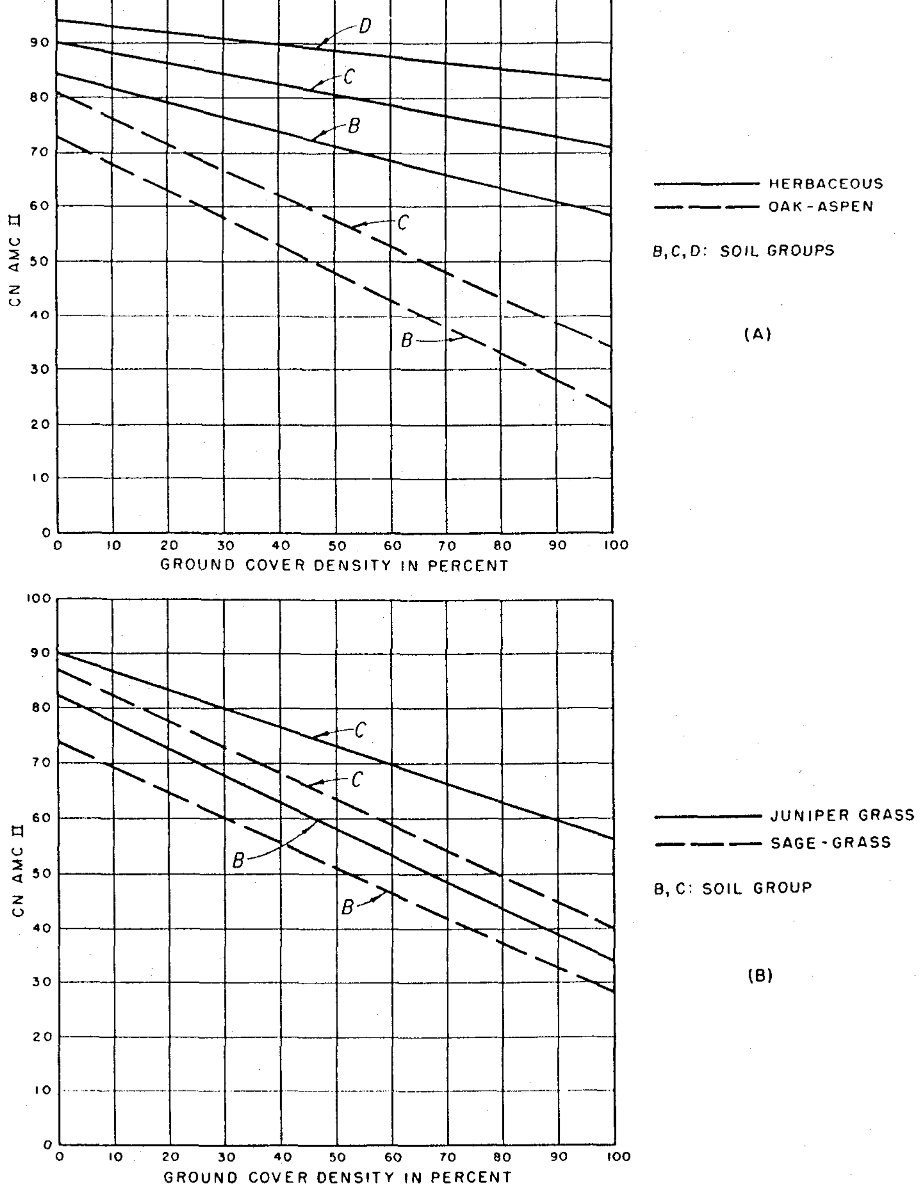


Figure 7-9. Runoff curve numbers for forest-range in the western U.S. (from U.S. Bureau of Reclamation, 1977).

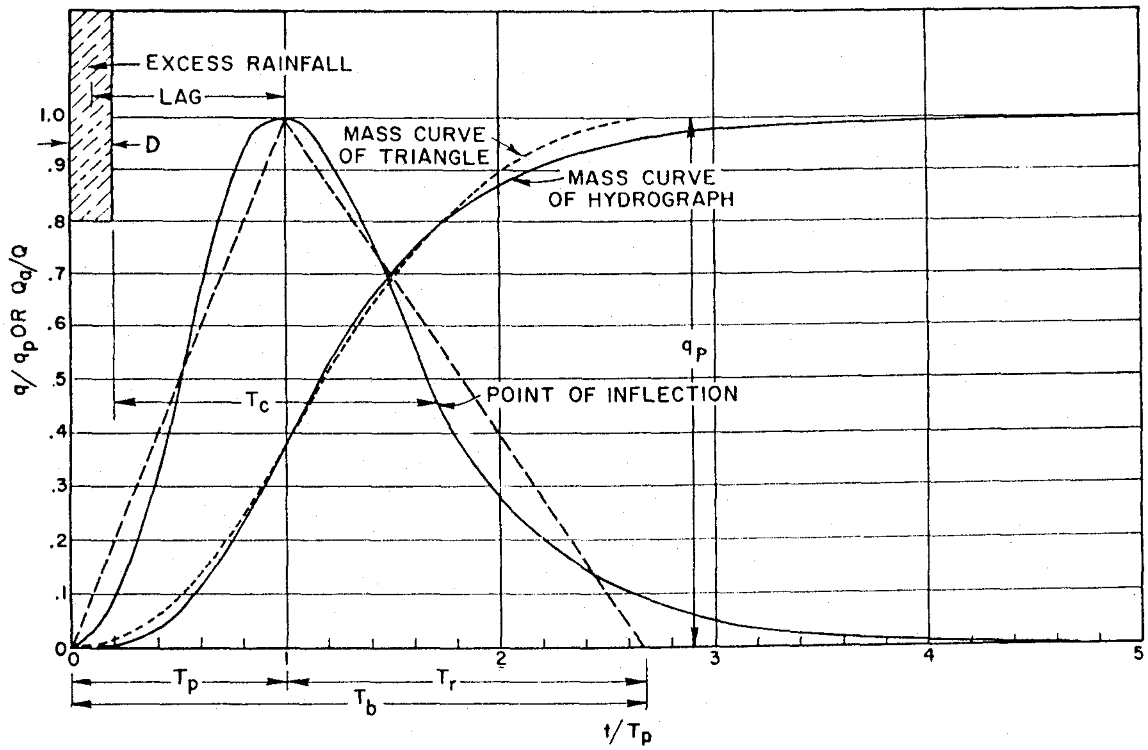


Figure 7-10. Curvilinear and triangular unit hydrographs (from U.S. Soil Conservation Service, 1972).

where q_p = peak flow rate (dimensioned according to Q and T) and other parameters have been previously defined.

When Q is expressed in inches and T_p in hours, q_p will be in inches per hour. The flow at any time $0<t<T_r$ may be determined by simple linear proportioning of the triangular unit hydrograph. The time to peak is related to the familiar expression time of concentration (T_c) by the equation,

$$T_c + t = 1.7T_p \qquad (7\text{-}5)$$

in which the factor 1.7 is an empirical finding cited by the U.S. Soil Conservation Service (1972).

The time of concentration may be estimated by several formulas. For this report, T_c was determined from the following equations (U.S. Soil Conservation Service, 1972):

$$L = \frac{\ell^{0.8} (S+1)^{0.7}}{1900 Y^{0.5}} \qquad (7\text{-}6)$$

and

$$T_c = 1.67L \qquad (7\text{-}7)$$

where L = watershed lag (hours)
ℓ = hydraulic length of the watershed, or distance along the main channel to the watershed divide (feet)
S = watershed storage factor defined in Equation (2)
Y = average watershed slope (percent)
T_c = time of concentration (hours)

Diversions were designed to convey runoff from an undisturbed area away from the disturbed site using the Manning and continuity equations:

$$V = \frac{1.486}{n} R^{0.67} S^{0.50} \qquad (7\text{-}8)$$

and

$$Q = AV \qquad (7\text{-}9)$$

where V = velocity (feet per second)
R = hydraulic radius (feet)
S = hydraulic slope (feet per foot)
n = roughness coefficient
Q = discharge (cubic feet per second)
A = flow area (square feet)

Values of the roughness coefficient required for the solution of Equation (7-8) were obtained by comparing local conditions with tabulated values provided by the U.S. Soil Conservation Service (1956). An empirical formula developed by Anderson et al. (1970) was used to determine the roughness coefficient for riprap linings.

Calculations with Equations (7-8) and (7-9) were performed using an interactive computer code entitled TRAP1 as obtained from the U.S.Office of Surface Mining and outlined by Weider et al. (1983). This code was used to determine flow conditions in the diversion channel at the design flow rate.

The sedimentation pond at the downstream edge of the site has been designed with a primary and emergency spillway. The primary spillway consists of a CMP riser and pipe through the embankment while the emergency spillway consists of a riprapped overflow at the corner of the embankment.

At low heads, the hydraulic capacity of the primary spillway behaves as a weir. According to Barfield et al.(1981), the equation for weir-controlled flow is

$$Q = CLH^{1.5} \qquad (7\text{-}10)$$

where Q = discharge (cubic feet per second)
C = weir coefficient
L = length of the weir (feet)
H = depth of water above the weir crest (feet).

A value of the weir coefficient equal to 3.1 was selected since the structure will act as a broad-crested weir (Barfield et al., 1981). The length of the weir is equal to the circumference of the CMP riser.

As the depth of water increases above the riser, the riser acts like an orifice. The equation for orifice flow is (Barfield et al., 1981)

$$Q = C'A(2gH)^{0.5} \qquad (7\text{-}11)$$

where C'= orifice coefficient
A = cross-sectional area of the inlet (square feet)
g = gravitational constant (feet per second squared)

and other parameters have been previously defined. A value of 0.60 was selected for the orifice coefficient based on guidelines presented by Barfield et al.(1981).

Pipe flow occurs when the head increases sufficiently to cause the outlet of the discharge pipe leading from the riser to flow full. The discharge capacity of the culverts under pipe flow conditions was determined using the equation,

$$Q = A(2gH')^{0.5}/(1+K_e+K_b+K_cL)^{0.5} \qquad (7\text{-}12)$$

where H' = head on the pipe (feet)
K_e = entrance loss coefficient
K_b = bend loss coefficient
K_c = friction loss coefficient

and all other parameters have been previously defined. Values of 1.0, 0.5, and 0.062 were used for K_e, K_b, and K_c, respectively based on information provided by Barfield et al. (1981).

The discharge capacity of the emergency spillway was determined using a method developed by the U.S. Soil Conservation Service (1968) and expanded by Barfield et al. (1981) for broad-crested weirs. According to this methodology, the critical specific energy head (H_{ec}) is determined for selected values of the energy head of water in the pond (H_p) from Figure 7-11. The discharge capacity of the spillway is then calculated for the standard 100-foot wide rectangular section from the equation,

$$q_r = (0.544)(g^{0.5})(H_{ec}{}^{1.5})(100) \qquad (7\text{-}13)$$

where q_r = discharge for standard 100-foot rectangular section (cubic feet per second)

and all other parameters have been previously defined. The flow is then corrected for a trapezoidal section using the equation,

$$q = ([1.5b + zH_{ec}]/150)(q_r) \qquad (7\text{-}14)$$

where q = corrected discharge (cubic feet per second)
b = bottom with of channel (feet)
z = channel side slope (run over rise - dimensionless).

The hydraulics of the spillway system was determined by assuming the pond was dewatered to the top of the sediment storage level prior to inflow from the 25-year, 24-hour storm.

7.2.1.3 Stability Analyses

Due to space restrictions, the sediment pond for the mine site was designed with upstream and downstream slopes both equal to 2h:lv. Since UMC 817.46(m) requires a combined slope of 5h:lv, a stability analysis was conducted to ensure that the pond embankment, as designed, would be stable.

The stability analysis was conducted using a microcomputer version of the program entitled STABL2 (Siegel, 1978). The

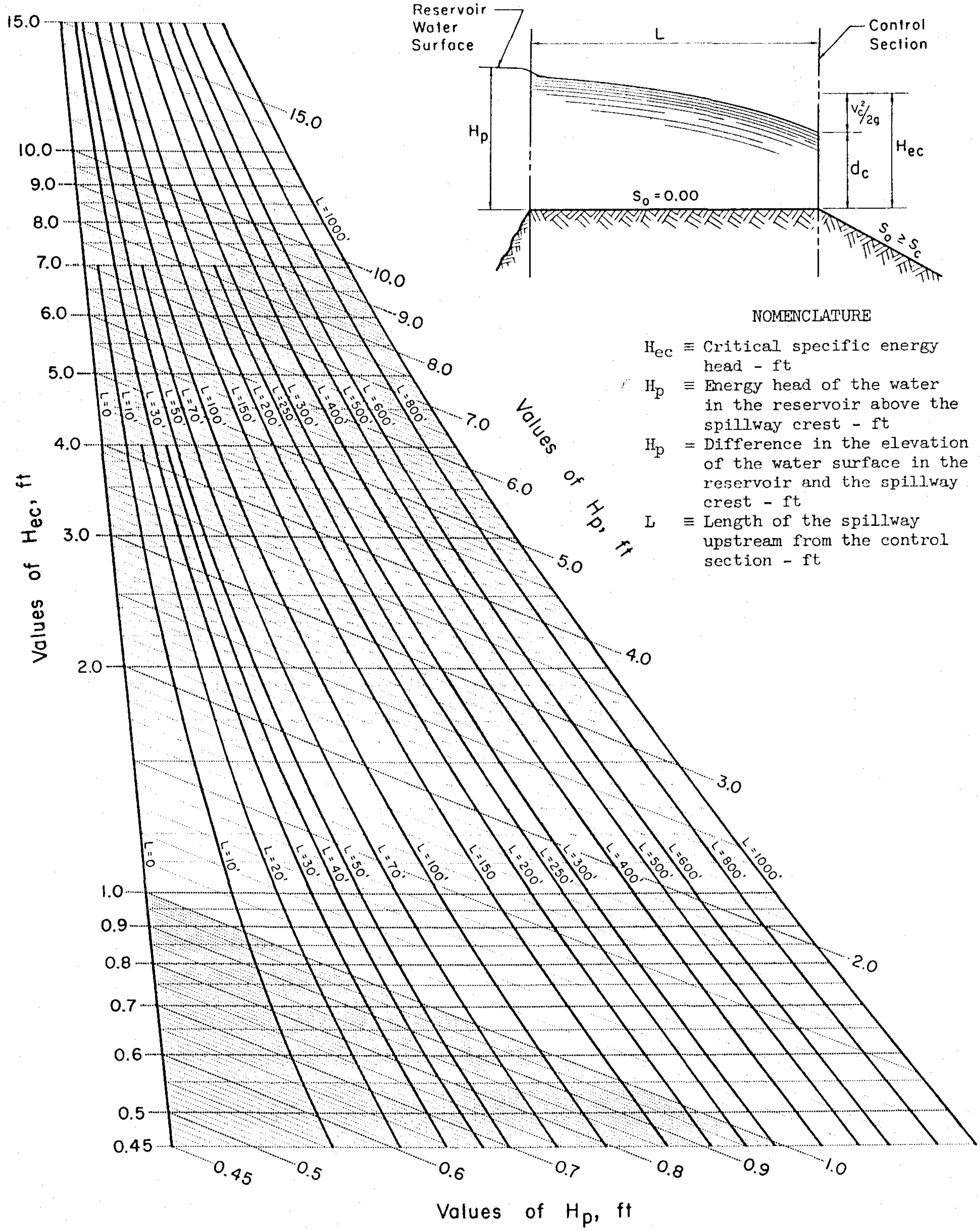


Figure 7-11. Head relationships for selected broad-crest weirs (from U.S. Soil Conservation Service, 1968)

modified Bishop method was used to calculate the factor of safety under both static and seismic conditions. Stability was modeled assuming both full and empty ponds, both with and without the designed clay liner functioning. Results of these analyses are presented in Section 7.2.3.2 and Appendix 7-6.

7.2.2 EXISTING SURFACE WATER RESOURCES

7.2.2.1 Regional Surface Water Hydrology

Crandall Creek is an east-flowing tributary of Huntington Creek, one of the major tributaries of the San Rafael River. Huntington Creek had annual flows near Huntington ranging from 25,000 to 150,000 acre-feet during the period of October 1931 through September 1973, averaging 65,000 acre-feet per year (Waddell et al., 1981). Variations in the annual flow of Huntington Creek near Huntington are portrayed graphically in Figure 7-12.

Approximately 50 to 70 percent of streamflow in the mountain streams of the region occurs during May through July (Waddell et al., 1981). Streamflow during this late spring/early summer period is the result of snowmelt runoff.

The quality of water in Huntington Creek and other similar streams in the area varies significantly with distance downstream. Waddell et al. (1981) found that concentrations of dissolved solids varied from 125 to 375 milligrams per liter in reaches of major streams above major diversions to 1600 to 4025 milligrams per liter in reaches below major irrigation diversions and population centers. The major ions at the upper sites were found to be calcium, magnesium, and bicarbonate, whereas sodium and sulfate became more dominant at the lower sites. They attributed these changes to (a) diversion of water containing low dissolved solids concentrations, (b) subsequent irrigation and return drainage from moderate to highly saline soils, (c) groundwater seepage, and (d) inflow of sewage and pollutants from population centers.

Average annual sediment yields within the Huntington Creek drainage basin range from approximately 0.1 acre-feet per square mile in the headwaters area to about 3.0 acre-feet per square mile near the confluence with the San Rafael River (Waddell et al., 1981). Increases in sediment yield with increasing distance downstream is generally the result of increasing amounts of shale and sandstone in the downstream direction (Waddell et al., 1981).

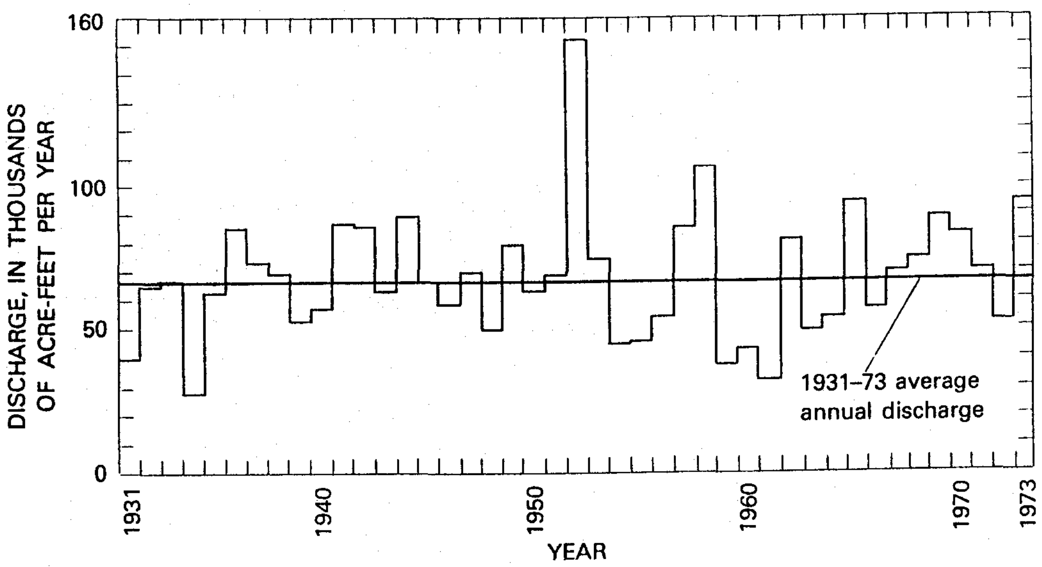


Figure 7-12. Annual discharge of Huntington Creek near Huntington (from Waddell et al., 1981).

7.2.2.2 Mine Plan Area Surface Hydrology

The permit area is drained entirely by ephemeral watersheds. These watersheds are steep (with average slopes often exceeding 50 percent) and well vegetated (with percent covers also often exceeding 50 percent).

Flow data collected at the U.S. Geological Survey gaging station at the mouth of Crandall Creek are contained in Appendix 7-2. These data are summarized in Figures 7-13 (monthly flow volumes) and 7-14 (monthly maximum and minimum flow rates) for the period of record (October 1978 - September 1984). Data collected from the USGS gaging station location at the mouth of Crandall Canyon was discontinued by the USGS in 1984.

As noted in Figures 7-13 and 7-14, the flow data for Crandall Creek are not complete for the winter months in most years, due presumably to data acquisition problems. However, the limited data indicate that most of the flow of Crandall Creek occurs in the period of May through July, in keeping with the conclusions of Waddell et al. (1981). Assuming an average flow of 30 acre-feet per month for the period of missing record, the average annual flow for the six-year period of data contained in Appendix 7-2 was 2740 acre-feet.

According to Figure 7-14, maximum flow rates in Crandall Creek normally occur in the month of May or June, while minimum recorded flows occurred during the months of September through November. During the period of record, the maximum recorded daily flow rate has been 88 cubic feet per second (on May 30, 1983). The minimum recorded daily flow rate has been 0.28 cfs (on several days in September 1981) during the same period. Lower minimums may have occurred during the period when data are lacking.

Plan and profile views of Crandall Creek adjacent to the surface facilities are shown on Plate 7-1. Selected cross sections are provided on Plate 7-2. As noted, Crandall Canyon is steep, with channel slopes normally exceeding 5 percent. The channel bottom is approximately 10 feet wide and side slopes are steep (generally greater than 100 percent).

Surface water-quality data collected from Crandall Creek by Genwal are contained in Appendix 7-3 and summarized in Table 7-5a. These data, collected between June 1983 and November 1985, indicate that the dominant ions in Crandall Creek are calcium and bicarbonate. Total dissolved solids concentrations in the stream have varied form 180 to 286 milligrams per liter, with lower concentrations normally occurring during the high-flow season.

Total suspended solids concentrations in Crandall Creek have varied during the period of record from <0.5 to 5.0 milligrams

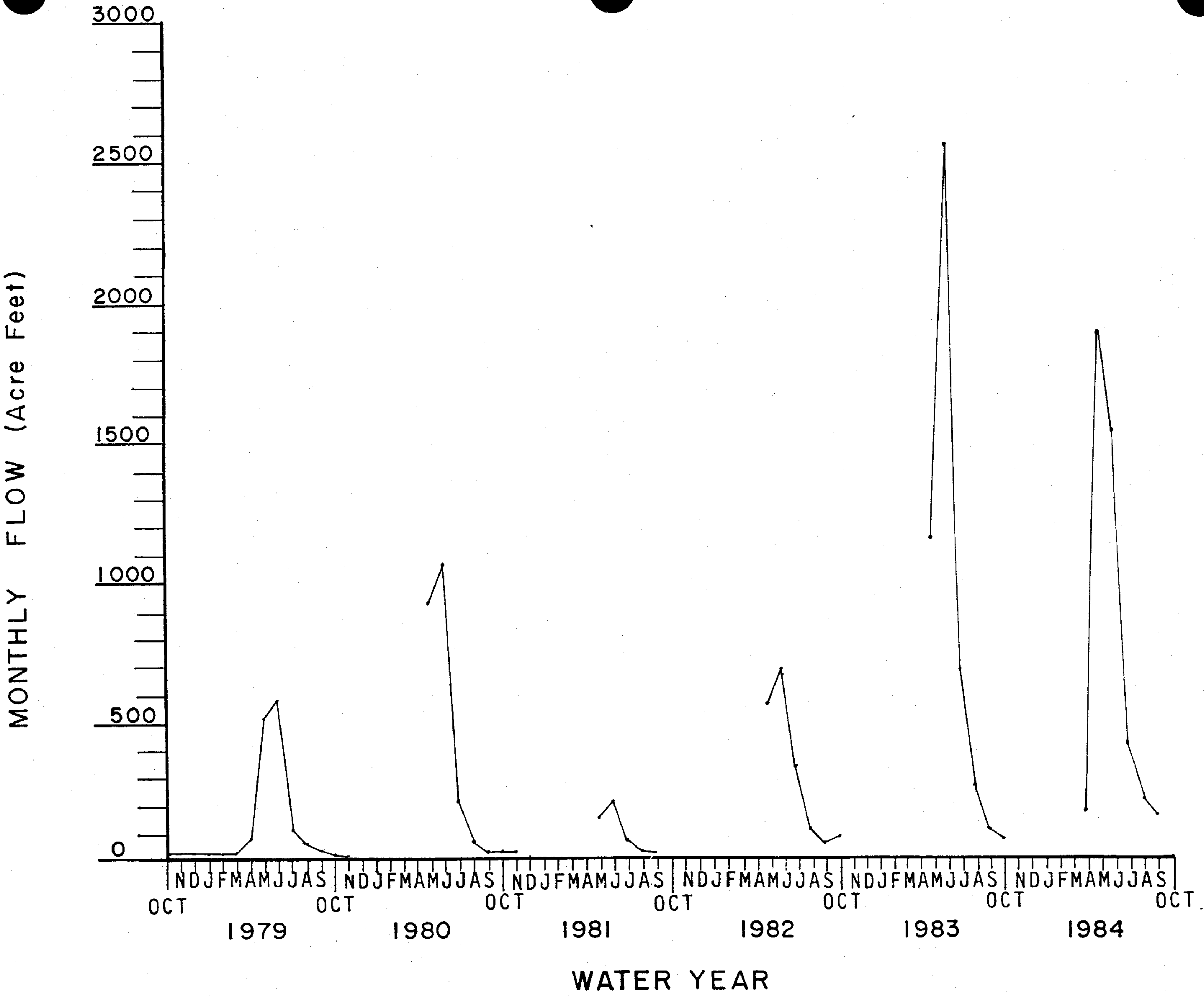


Figure 7-13. Monthly flow of Crandall Creek near Huntington.

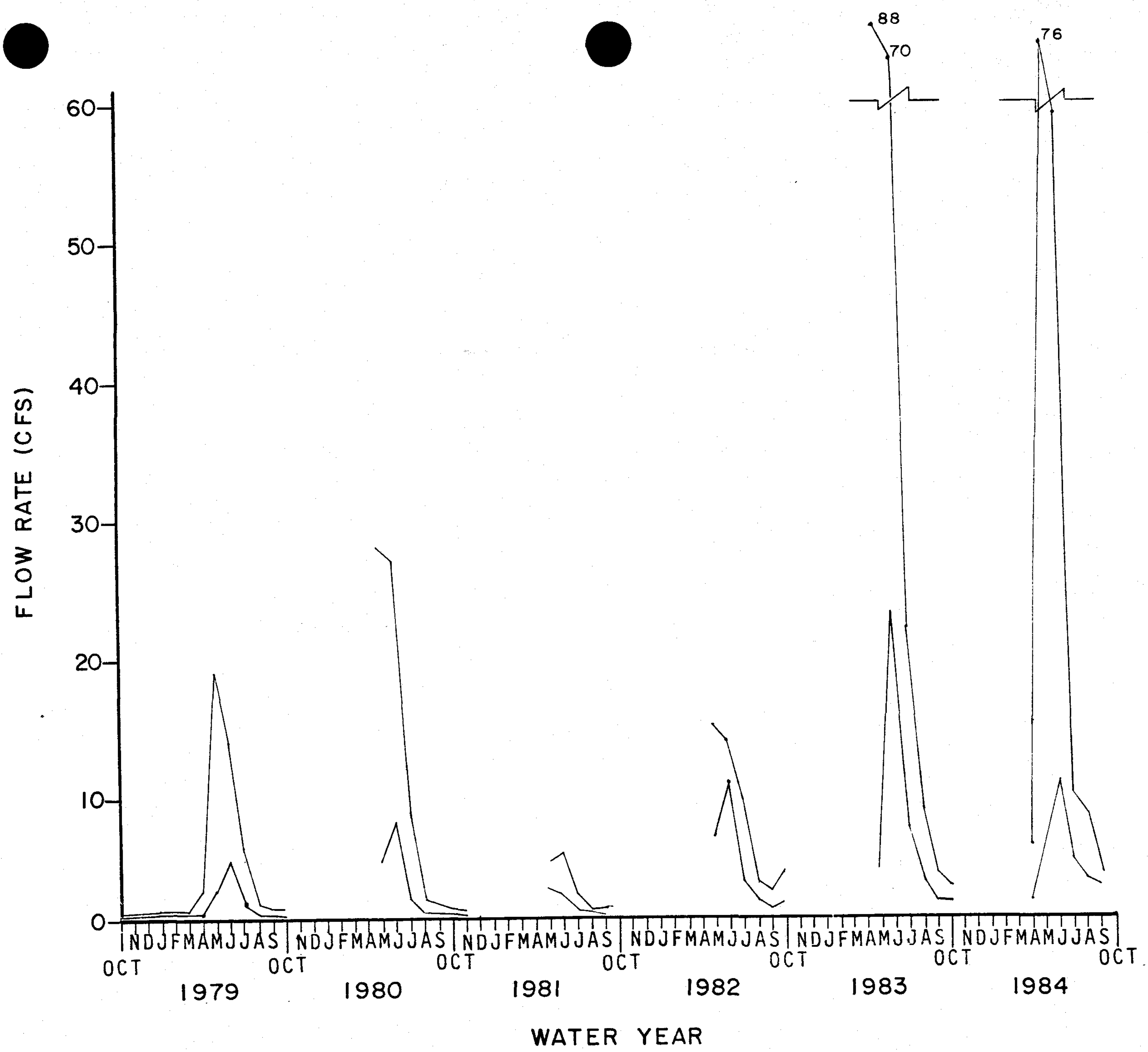


Figure 7-14. Maximum and minimum daily flows of Crandall Creek near Huntington.

Table 7-5a. Concentrations of selected constituents in Crandall Creek.

Constituent	Maximum (mg/l)	Date	Minimum (mg/l)	Date	Mean (mg/l)
Upper Station[a] 60 Samples					
Total Diss. Solids	320	11/24/87	180	4/08/85	255
Total Susp. Solids	1472	5/16/84	0	7/17/86	59.3
pH[b]	8.28	10/29/86	6.75	11/14/84	7.78
Total Iron	0.34	6/28/83	<0.05	Several	0.06
Diss. Iron	<0.05	Several	<0.05	Several	<0.05
Total Manganese	0.03	Several	<0.01	Several	0.01
Lower Station[a] 52 Samples					
Total Diss. Solids	323	1/29/86	165	11/07/84	259
Total Susp. Solids	1468	5/16/84	0	7/17/86	57.8
pH[b]	8.66	11/20/86	6.95	11/01/84	7.75
Total Iron	0.25	6/28/83	<0.05	Several	<0.05
Diss. Iron	<0.05	Several	<0.05	Several	<0.05
Total Manganese	0.03	Several	<0.01	Several	0.01

(a)See Figure 7-14
(b)In standard pH units

per liter (see Appendix 7-3). As expected, the highest suspended solids concentrations generally occur during periods of highest flow.

7.2.3 SURFACE WATER DEVELOPMENT AND CONTROL

7.2.3.1 Water Supply

No extensive surface water development has occurred in the mine plan or adjacent areas. Genwal has historically pumped water from the stream near the sedimentation pond for use underground. However, no pumping has taken place over the previous two years. Once the magnitude of the minimum instream flow is established, Genwal agrees to not pump from Crandall Creek at a rate that will cause the instream flow to decrease below the minimum required rate. For the purpose to this determination, flow rates well be measured using the flume at the "Lower Stream Station" indicated on Figure 7-20. No other points of development are known to exist on Crandall Creek or adjacent streams in the immediate vicinity of the mine plan area.

Genwal, in consultation with the U.S. Forest Service, will determine the appropriate base-line stream flows which should be maintained in Crandall Creek during pumping episodes.

Table 7-6 presents a listing of surface water rights within the permitted and adjacent areas as obtained from the files of the Utah Division of Water Rights in September 1987. More indepth information concerning these rights is contained in Appendix 7-1. Locations of these rights are noted on Figure 7-15.

All surface water rights noted in Table 7-6 and Figure 7-15 are held by the U.S. Forest Service for stock watering purposes. However, during the two 1985 seep and spring surveys, no signs of stock usage of the area were noted. Thus, although the rights exist, usage of these rights is apparently curtailed.

Only one water-supply intake is known to exist on Crandall Creek. This intake is located immediately upstream from the sedimentation pond and is operated by Genwal to obtain water for use at the mine. A search of records on file with the Utah Division of Water Rights and an examination of physical conditions along Crandall Creek and Huntington Creek indicate that no other water-supply intakes exist within one mile from the confluence of the two streams.

Table 7-6. Surface water rights in the mine plan and adjacent areas.

W.U. Claim No.	Owner	Flow (cfs)	Use	Period of Use	Source
93-182	U.S. Forest Service	(a)	Stockwater	May 21 to Aug 30	Stream
93-183	U.S. Forest Service	(b)	Stockwater	June 6 to Aug 25	Stream
93-188	U.S. Forest Service	(a)	Stockwater	May 21 to Aug 30	Stream
93-190	U.S. Forest Service	(a)	Stockwater	May 21 to Aug 30	Stream
93-191	U.S. Forest Service	(b)	Stockwater	June 6 to Aug 25	Stream
93-483	U.S. Forest Service	(b)	Stockwater	June 6 to Aug 25	Stream
93-1180	U.S. Forest Service	(a)	Stockwater	May 21 to Aug 30	Stream

(a) Part of water right WUC 93-116 on Huntington Creek
(b) Part of water right WUC 93-1403 on Crandall Canyon Allotment

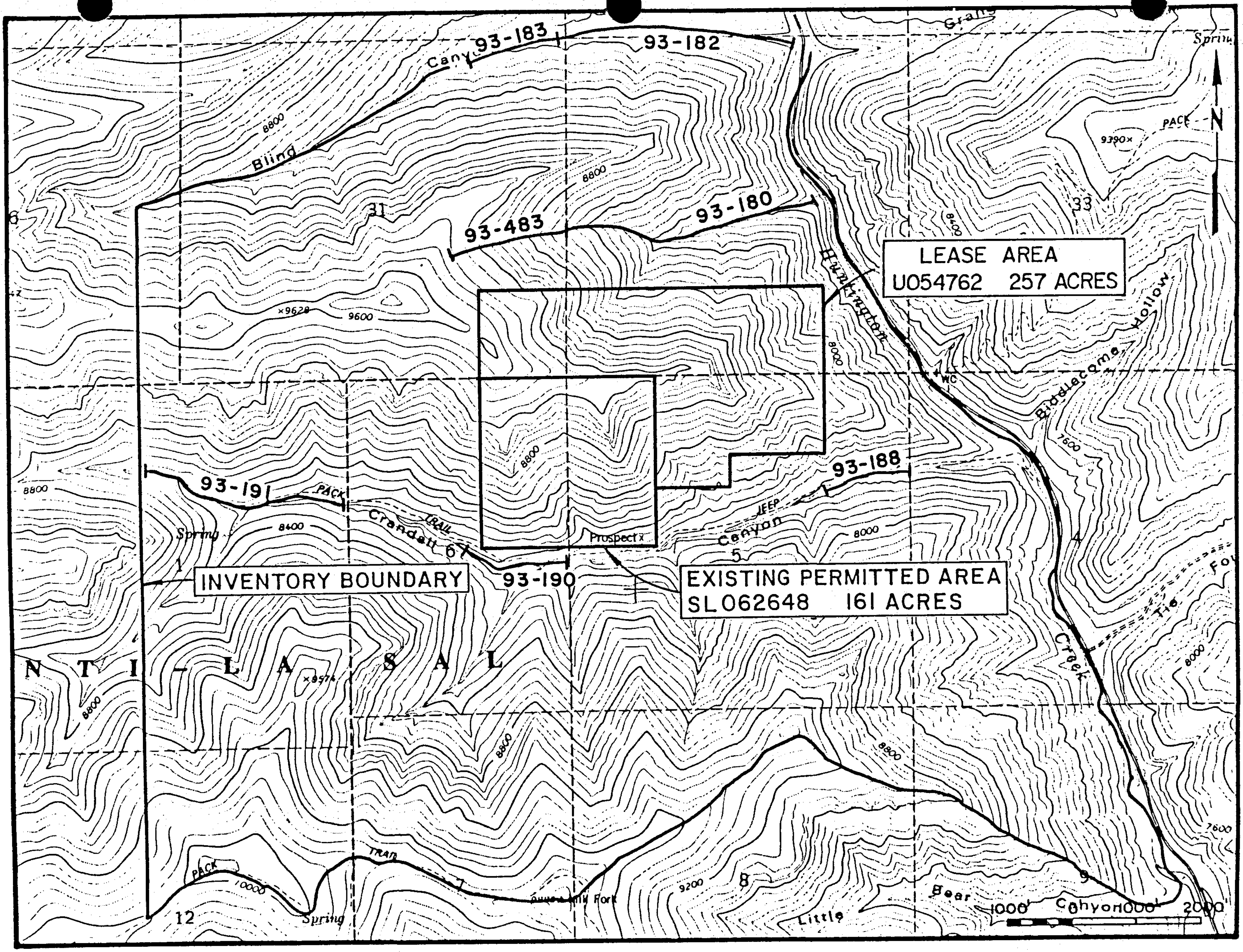


Figure 7-15. Location of Surface Water Rights in the Crandall Canyon Area.

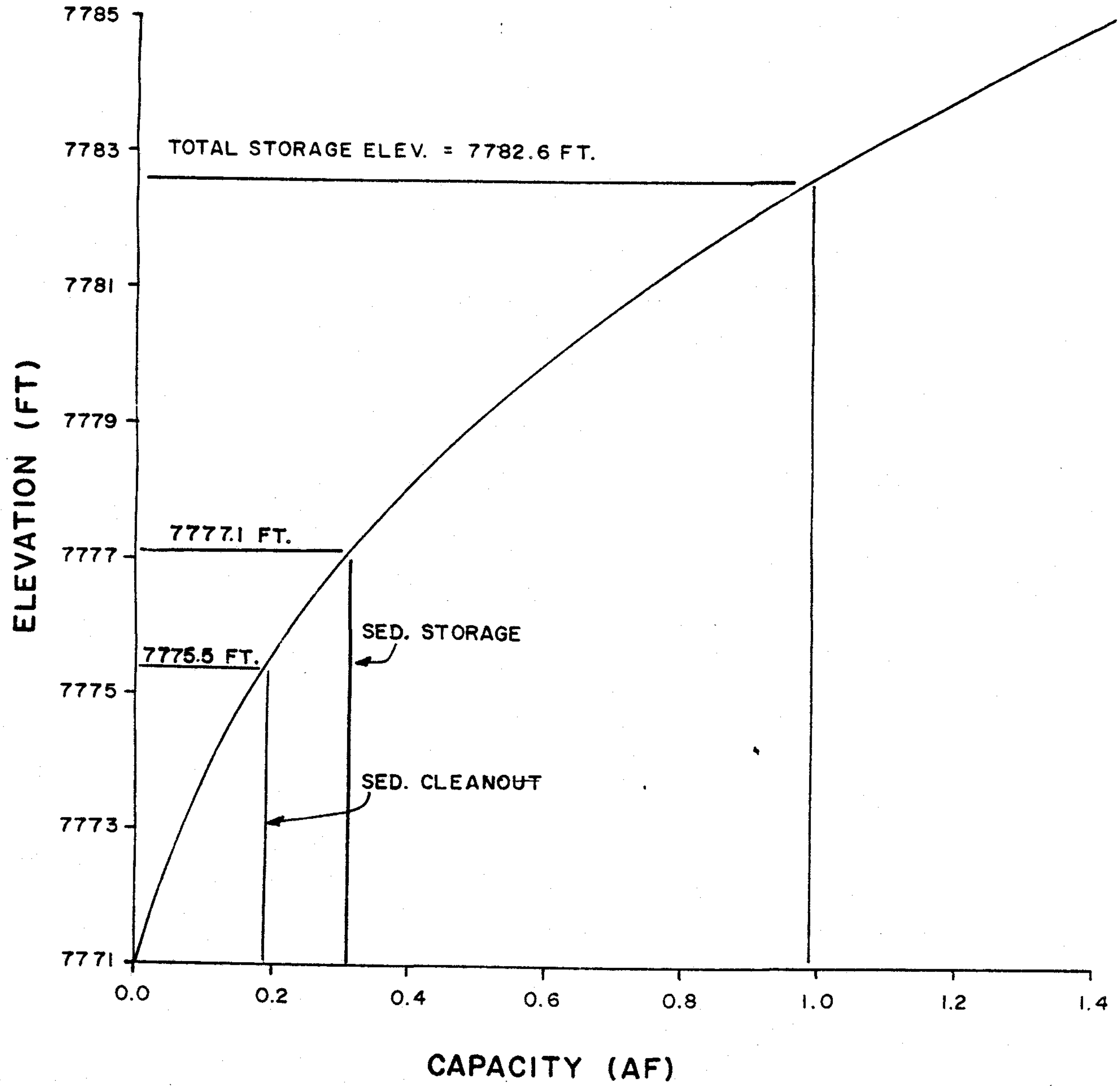


Figure 7-16. Stage-capacity curve for proposed sedimentation pond.

7.2.3.2 Runoff- and Sediment-Control Facilities

Results of analyses to determine the required size and hydraulics of the sedimentation pond are included in Appendix 7-4. In sizing the pond, plans for future expansion of the surface facilities at the Crandall Canyon Mine were accounted for. Details of the sedimentation pond required for compliance with 30 CFR 77.216-1 and 30 CFR 77.216-2 are contained in Appendix 7-8.

Runoff to the sedimentation pond from the 10-year, 24-hour storm was determined to be 0.68 acre-foot (with 0.30 acre-foot originating on reclaimed and undisturbed areas and 0.38 acre-foot originating on disturbed and ponded areas). Required sediment storage for the pond was determined to be 0.31 acre-foot, including 0.27 acre-foot from disturbed areas and 0.03 acre-foot from undisturbed and reclaimed areas over a 3 year period. Hence, the pond was designed with a total storage volume of 0.98 acre-foot.

Plate 7-4 presents details of the sedimentation pond design. Cross sections referred to on the plate are found on Plate 7-6. Based on the topographic map of the pond, the stage-capacity curve provided in Figure 7-16 was developed. This stage-capacity curve has taken account of the clay liner and the gravel marker noted on Plate 7-4.

As noted in Figure 7-16, the pond provides sediment storage to an elevation of 7777.1 feet and total storage (sediment plus runoff) to an elevation of 7782.6 feet. Sediment will be cleaned out of the pond when it reaches an elevation of 7775.5 feet at the riser (the elevation corresponding to a volume of 60 percent of the required sediment storage volume). Two steel stakes are placed at the locations shown on Plate 7-4 to mark the sediment-clean-out elevation of 7775.5 feet.

Sediment removed from the pond will be initially stored in the location noted on Plate 3-1. Permanent disposal of the sediment will be in accordance with Section 3.3.9.

A previous riser in the sedimentation pond had an overflow elevation of 7779.4 feet and a decant elevation of 7777.1 feet. The decant system was installed according to Plate 7-6 (i.e., at the top of the sediment storage level). A gate valve was installed as noted to allow manual draining of the pond. A locked cap was placed over the access port to the gate valve to prevent unauthorized entry. The key to this valve is kept at the Genwal office in Huntington. Under no circumstances will water be discharged from the sedimentation pond to Crandall Creek prior to 24 hours from the end of the runoff event to the pond.

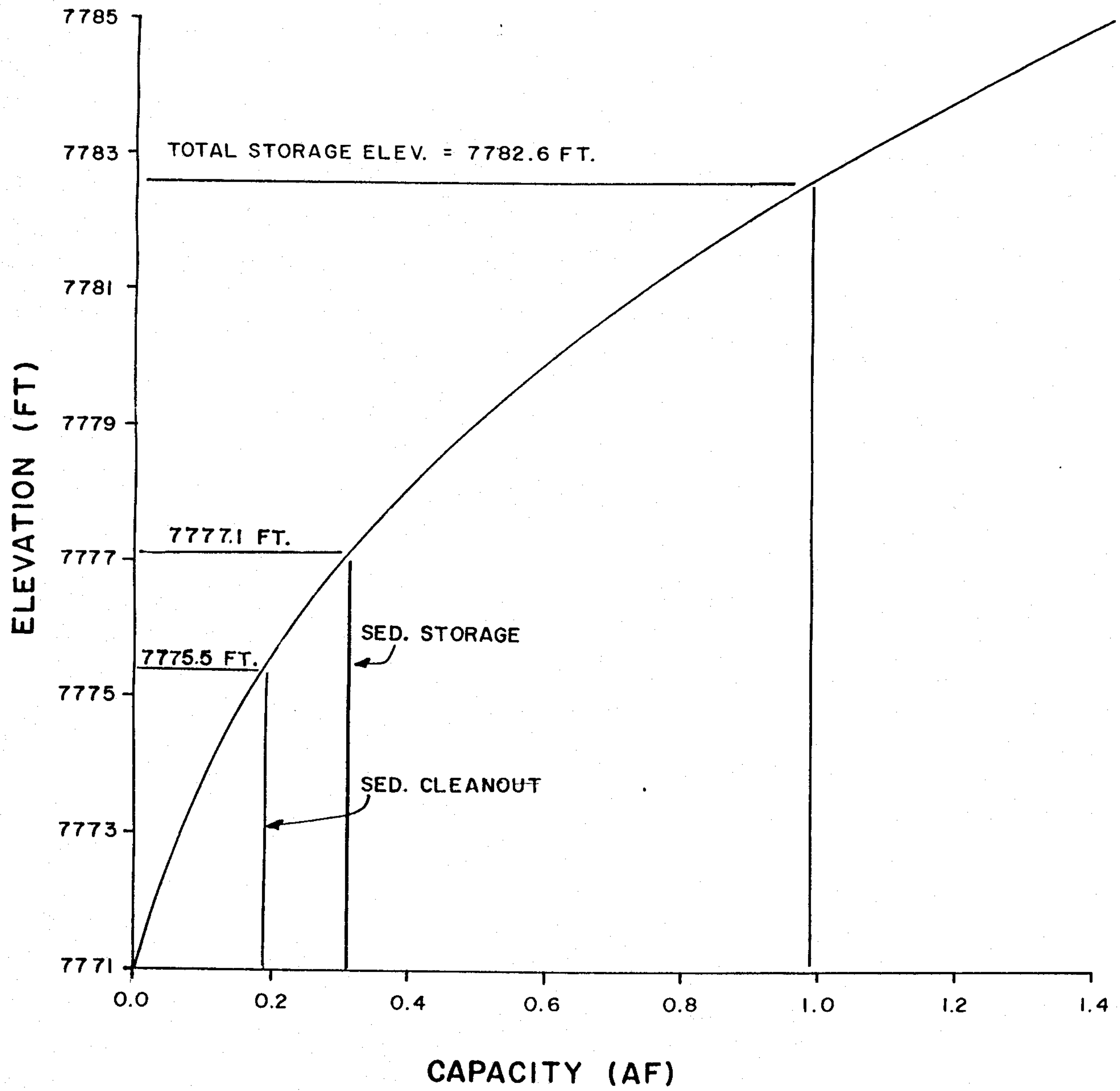


Figure 7-16. Stage-capacity curve for proposed sedimentation pond.

Prior to any discharges through the decant system on the sedimentation pond, a sample will be collected to determine total suspended solids, settleable solids, total dissolved solids, oil and grease, total iron, total manganese concentrations, and pH. This sample will be collected by opening the gate valve on the dewatering device, allowing water to flow from the pond through the primary spillway for a sufficient time to collect a sample of the water, and then immediately shutting the gate valve to prevent further dewatering. This sample will then be submitted to a laboratory for analyses of the indicated parameters.

After receipt of analytical results from the laboratory, if the pH and concentrations of total suspended solids, settleable solids, total dissolved solids, oil and grease, total iron, and total manganese are within the acceptable limits established by UMC 817.42 and the NPDES permit for the sedimentation pond, water will be discharged from the pond through the dewatering device. If the parameters of concern are not within the acceptable limits, no water will be discharged through the device.

The sedimentation pond will normally be dewatered directly to Crandall Creek. However, in the event of an emergency (e.g., runoff flowing into the pond when it is full but the quality of water in the pond is not sufficient to permit discharge to Crandall Creek), the pond will be pumped to the underground sump in the mine. No water will be discharged from the sump to the surface unless water in the sump is determined to meet the water-quality standards of UMC 817.42 and the NPDES permit. This will be determined by opening the valve to the discharge line for a sufficient time to allow collection of a sample at the NPDES discharge point (i.e., the sedimentation pond outlet). This sample will likewise be analyzed for the parameters of concern. If the analytical results indicate that the water is of adequate quality, it will be discharged to the surface. If the water is not of adequate quality, it will not be discharged.

During discharge of water to Crandall Creek from either the sedimentation pond or the underground sump, samples of the water will be collected at the discharge point at the beginning, middle, and end of the discharge time. These samples will be sent to a laboratory following the discharge period for analyses of total suspended solids, settleable solids, total dissolved solids, total iron, total manganese, oil and grease, and pH. Analytical results will be submitted to the Division within 10 working days of receipt of these results from the laboratory.

The outflow point on the riser was raised 3.2 feet to an elevation of 7782.6 feet (the top of the total storage pool). This was accomplished with a section of 24-inch CMP clamped to the existing riser.

During the spring of 1989, leakage was noted through joints located in the lower portion of the sedimentation pond riser. This leakage has caused a slight but continual discharge from the sedimentation pond. To alleviate this leakage, the lower portion of the riser and the existing barrel will be plugged with cement. A new barrel will be installed through and down the face of the embankment. This riser will extend to Crandall Creek, discharging onto natural riprap that exists at the toe of the dam. Details of the proposed alteration to the sedimentation pond primary spillway are provided on Plates 7-6 and 7-6A.

Results of inflow and outflow analyses from the 25-year, 24-hour storm using SEDIMOT II are presented in Appendix 7-4. It should be noted that the sedimentology option of SEDIMOT II was used during design only to permit routing of the hydrograph through the pond. However, since sediment contributions from the 25-year, 24-hour event are not of concern in design of the pond (only sediment yield from the 10-year, 24-hour and smaller storms is of regulatory concern), the sediment inputs to the model were suppressed. Thus, the output from the program indicates sediment concentrations of 0 milligrams per liter. Selected other outputs contained in Appendix 7-4 associated with sediment yield are, therefore, also meaningless.

It should also be noted that, although detention times shown on the output in Appendix 7-4 are relatively low (0.15 hour), these times have no regulatory meaning for a 25-year event (i.e., regulatory concerns address only the 10-year and smaller events). Again, the program was used primarily for its spillway-design capabilities and not for dealing with the specifics of sediment yield and detention times from the 25-year design event.

Utilizing the combined hydraulics of the primary and proposed emergency spillways, the peak outflow stage during the 25-year, 24-hour storm was calculated by SEDIMOT II as 6.0 feet above the sediment storage level. Thus, the outflow elevation during the design flow event was determined to be 7783.1 feet. The hydraulic effects of the primary spillway modification are discussed in Appendix 7-4. The effectiveness of energy dissipation of the discharge from the barrel of the spillway to the creek are also presented in Appendix 7-4.

The indicated outflow elevation during the design flow event (elevation 7783.1 feet) is lower than that of the proposed emergency spillway, indicating that water will not pass through the emergency spillway under design conditions. Nonetheless, an emergency spillway was installed at the request of the U.S. Forest Service to provide a factor of safety and a bypass for water during events larger than those for which the pond was designed. Conservatively, the emergency spillway crest was placed at an elevation of 7784.0. As designed, this spillway has a bottom width of 4.0 feet and side slopes of 2h:1v.

As noted on Plate 7-4, the emergency spillway will discharge onto the boulder-covered slope adjacent to the sedimentation pond. Boulders that cover this slope were blasted from the cut above the pond during construction of the mine-access road. Due to the large size of the boulders, laboratory size-fraction analyses could not be conducted. However, the boulders are visually estimated to range in size up to at least 10 feet in diameter. It is further estimated that approximately 80 percent of the coarse rock on the slope is finer than 8 feet in diameter, 30 percent is finer than 5 feet in diameter, and 10 percent is finer than 3 feet in diameter.

The blasted rock has an approximate thickness of 15 to 20 feet at the top of the slope and 5 to 6 feet at the bottom of the slope. The soil that underlies the rock is a silty sand. Size-fraction analyses presented by Delta Geotechnical Consultants (1982) indicate that this soil is 70 percent sand and 30 percent silt and clay (the latter being minus 200 mesh).

The emergency spillway is lined with riprap and a filter blanket as noted in Appendix 7-4 to reduce erosion potential. Grading of the riprap, filter blanket, and embankment materials are shown in Figure 7-17. Design of this filter blanket is presented in Appendix 7-4. The spillway will discharge directly onto the boulder-covered slope. Due to the extreme thickness of the boulders and cobbles on the slope, additional erosion protection below the emergency-spillway outflow will not be required.

Since the emergency spillway will not be flowing during the design event, UMC 817.46(j) requires only that the top of the settled embankment be 1.0 foot above the crest of the emergency spillway. This will result in an embankment crest elevation of 7785.0 feet. The crest of the existing embankment was at an elevation of 7783.0 feet, the design required the addition of 2.0 feet of settled embankment to the top of the existing embankment. No additional material will be added to account for settlement since (a) the embankment is being raised 0.4 feet more than required and (b) the existing embankment is assumed to have settled previously.

With a crest elevation of 7785.0 feet and a base elevation of 7771.0 feet at the upstream toe, the embankment has a height of 14.0 feet. Using the equation provided in UMC 817.46(l), the required top width of the embankment is 9.8 feet. An actual top width of 10.0 feet was constructed.

The existing pond was enlarged to meet the volume requirements of this plan by removing excess fill from the interior of the pond. In addition, the upper 12 feet of the exterior of the existing embankment was recontoured to a slope of 2h:lv. Prior to recontouring the exterior slope, all large rock fragments were removed.

All new fill required to raise the embankment was placed in 6-inch lifts. This new fill was compacted in place by repeated passes of a front-end loader or equivalent prior to placing the next lift. Compaction continued until the density of the material was at least 90 percent of Proctor density (as determined by sand-cone density tests in the field).

Because of the location of the sedimentation pond on a hillside between the access road and Crandall Creek, insufficient space was available to permit construction of side slopes with a combined upstream and downstream slope of 5h:lv and still provide the required storage capacity. Hence, the pond has been designed with 2h:lv side slopes on both the upstream and downstream sides.

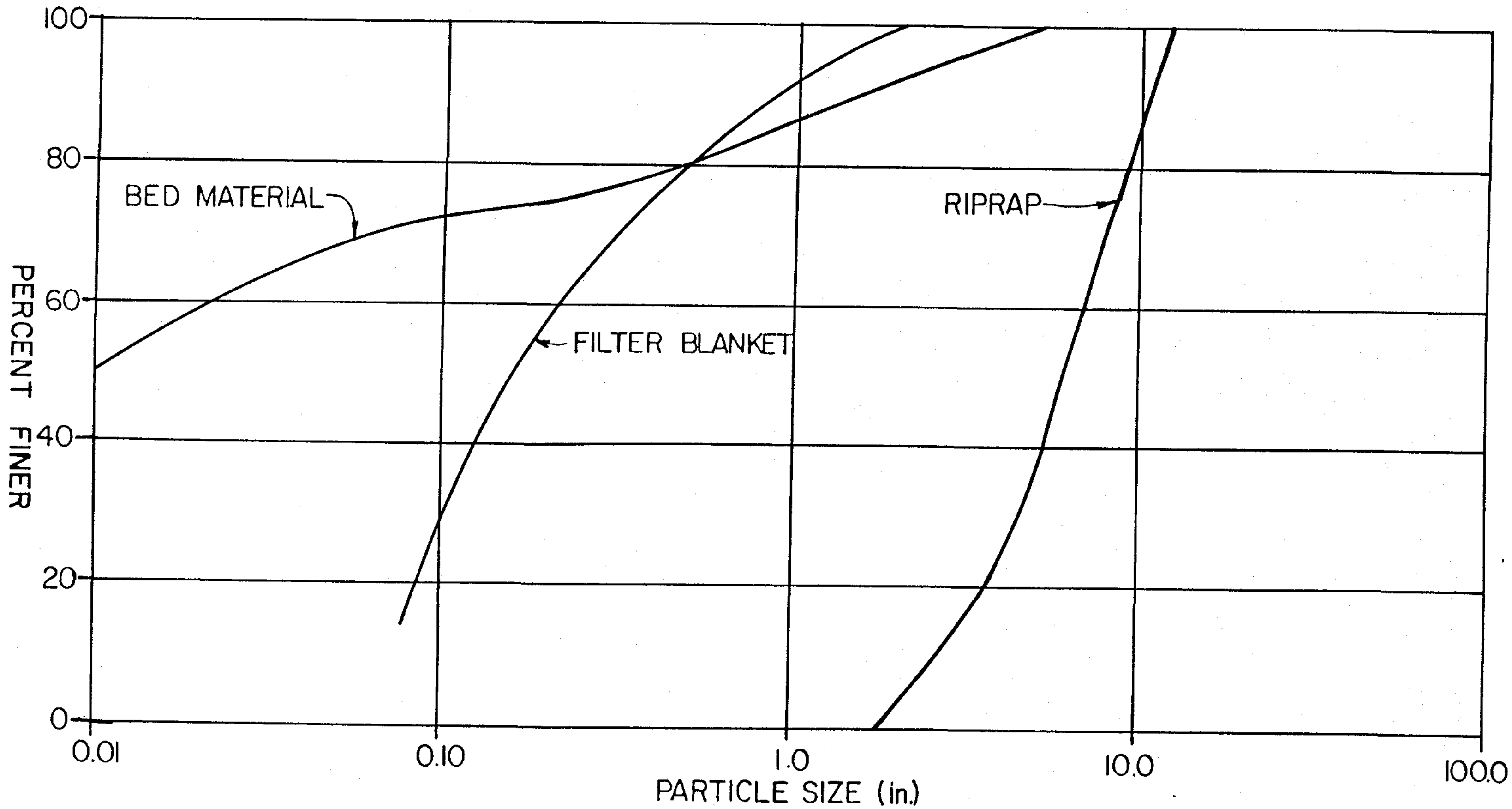


Figure 7-17. Gradation of embankment, filter, and riprap materials.

As included in the original design, the interior of the pond was lined with a 12-inch thick local, compacted clay to reduce seepage from the pond and, thereby, increase the stability of the embankment. The clay liner was placed in 6-inch lifts and compacted during placement by at least four passes of a front-end loader or equivalent. The initial layer was disk-harrowed into the bottom of the pond prior to compaction.

After pond cleanout, the thickness of the clay liner will be sampled by means of a bucket auger at 8 locations. Three holes will be placed along the ingress/egress route and five additional holes will be randomly selected from the remaining pond area. If any of the holes penetrate less than 10 inches of clay, additional clay will be compacted into the deficient areas of the pond.

All new construction on the revised sedimentation pond was supervised by a Professional Engineer who is licensed in the State of Utah. An initial certification report was prepared and certified by the supervisory PE for submission to DOGM following completion of construction activities. Plate 7-4a shows as-built drawings of the pond and riser detail. Plate 7-6a shows as-built cross sections through the pond. Appendix 7-10 contains as-built calculations for the sedimentation pond and the initial certification report. The initial certification report previously submitted to DOGM included:

- Existing and required monitoring procedures and instrumentation
- The design depth and elevation of any impounded waters at the time of the report
- Existing storage capacity of the dam or embankment
- A discussion of any fires occurring in the construction material up to the date of certification
- A discussion of any other aspects of the dam or embankment affecting stability

Flow conditions in Crandall Creek adjacent to the sedimentation pond were examined to determine if flood flows may erode the downstream toe (see Appendix 7-5). As noted, the peak flow from the 100-year, 24-hour precipitation event will encroach 0.6 foot above the toe of the embankment. Thus, a riprap protective layer (with a median rock diameter of 12.5 inches) was placed along the lower 2.0 feet of the embankment as shown in Plate 7-4. Placement of this riprap will serve an incidental purpose of increasing the stability of the dam by placing additional weight on the downstream toe.

Although the presence of the sedimentation-pond dam adjacent to Crandall Creek may slightly alter flow conditions in the stream, the placement of erosion-protection features on the steep stream bank across from the pond is not considered justified for two reasons. First, placement of erosion-protection features on the bank across from the pond will likely cause more disturbance than it will prevent due to the steepness of the bank. Second, as noted in Appendix 7-5, the peak flow event for which the analysis was conducted has an estimated return period in excess of 10,000 years (due to the conservativeness of the storm distribution used in the analysis), indicating the remoteness of the possibility that the stream might overtop its banks and impinge on the dam.

As a result, while the pond is in operation, the stream bank across from the pond will be inspected each time the piezometer through the dam is monitored (see Section 7.2.6). If erosion occurs on the opposite stream bank due to the presence of the pond, a repair plan will be prepared and implemented in consultation with DOGM.

An analysis was conducted of the pond to determine the stability of the dam under selected conditions. Cross sections used for the analysis are shown on Plate 7-4, as are locations where Shelby-tube soil samples were collected for laboratory analyses to determine local soil properties. Results of the laboratory and stability analyses are presented in Appendix 7-6 and summarized in Table 7-7.

The required safety factors shown in Table 7-7 were developed in consultation with DOGM in a meeting on April 2, 1986 among Randy Hardin and Rick Summers of DOGM, Andrew C. King of Genwal, and Richard B. White of EarthFax Engineering, Inc. A comparison of the required and actual safety factors indicates that the embankment as designed will be stable. It should be noted that these safety factors did not include the benefits due to installation of the riprap on the dam toe as discussed above.

Following construction of the sedimentation pond as designed herein, all disturbed areas associated with pond construction (with the exception of the interior of the pond) were revegetated with the seed mixture noted in Section 3.5.5.2 of this PAP. This mixture was developed in consultation with Lynn Kunzler of the Division and Walt Nowak of the U.S. Forest Service. This mixture provides rapid growth species, sod-forming species, and species that are compatible with other plants.

Seeding was done in the late fall of 1986, just prior to the first heavy snowfall of the year (Plummer et al., 1968). Seeding was accomplished by broadcasting with a cyclone seeder. Mulch was placed after seeding. The mulch, which consisted of two tons

Table 7-7. Summary of slope stability analyses.

Cross Section[a]	Condition	Minimum Safety Factor	Required Safety Factor
A-A'	Unsaturated, static	2.20	1.50
	Unsaturated, seismic	1.76	1.10
	Saturated, static	1.19	1.00
B-B'	Unsaturated, static	2.00	1.50
	Unsaturated, seismic	1.56	1.10
	Saturated, static	1.08	1.00
C-C'	Unsaturated, static	2.23	1.50
	Unsaturated, seismic	1.67	1.10
	Saturated, static	1.38	1.00

[a] See Plate 7-4

of straw or grass hay per acre of disturbed area, was spread over the area to be planted and crimped into the soil with a roto-tiller or shovel to aid in moisture retention (U.S. Soil Conservation Service, 1975).

Following seeding, the revegetated outslopes of the pond were inspected during normal pond inspections to determine the effectiveness of the seeding. As of Fall 1987, the revegetation effort appears to have been successful on the outslopes of the pond. Straw-bale dikes were added as necessary to control excessive gullying on the dam face. These dikes were installed as noted by Figure 7-18.

In addition to revegetating the outslope of the pond with the grass seed mix noted in Section 3.5.5.2, consideration was given to planting phreatophytes indigenous to the riparian community of Crandall Creek. However, the decision was made to not plant riparian vegetation for the following reasons:

- The presence of deep-rooted riparian vegetation often encourages rodent burrowing, thereby reducing the stability of the dam.

- Because the roots of phreatophytes are generally larger than those of grasses, roots of those riparian plants that die cause significant weakening of the dam upon decay.

- UMC 817.46(s) requires that interim revegetation of the pond embankment be conducted to stabilize the embankment "with respect to erosion". The plan proposed above (planting with grass species and installation of straw-bale dikes as necessary) will minimize erosion of the face of the dam due to overland flow. Erosion of the toe of the dam due to flood flows in Crandall Creek will be minimized with the addition of a layer of riprap along the toe as also outlined above.

Small-area exemptions are requested for the seven areas shown on Plate 7-5 and Figure 7-18a. SAE-1 (with a surface area of 0.02 acre) is the outslope of the access road to the administration pad at the western end of the surface facilities as well as to proposed U.S. Forest Service facilities to be located upstream from the mine facilities. Runoff from this area cannot feasibly drain to the sedimentation pond without excessive disturbances adjacent to Crandall Creek.

Runoff will occur from SAE-1 as sheet flow toward Crandall Creek. The area was reclaimed as outlined in Section 3.5 for contemporaneous reclamation. Reclamation commenced during the autumn 1986 immediately following completion of construction associated with the area. Maintenance of the revegetation effort will occur as outlined in Section 3.5. Immediately following

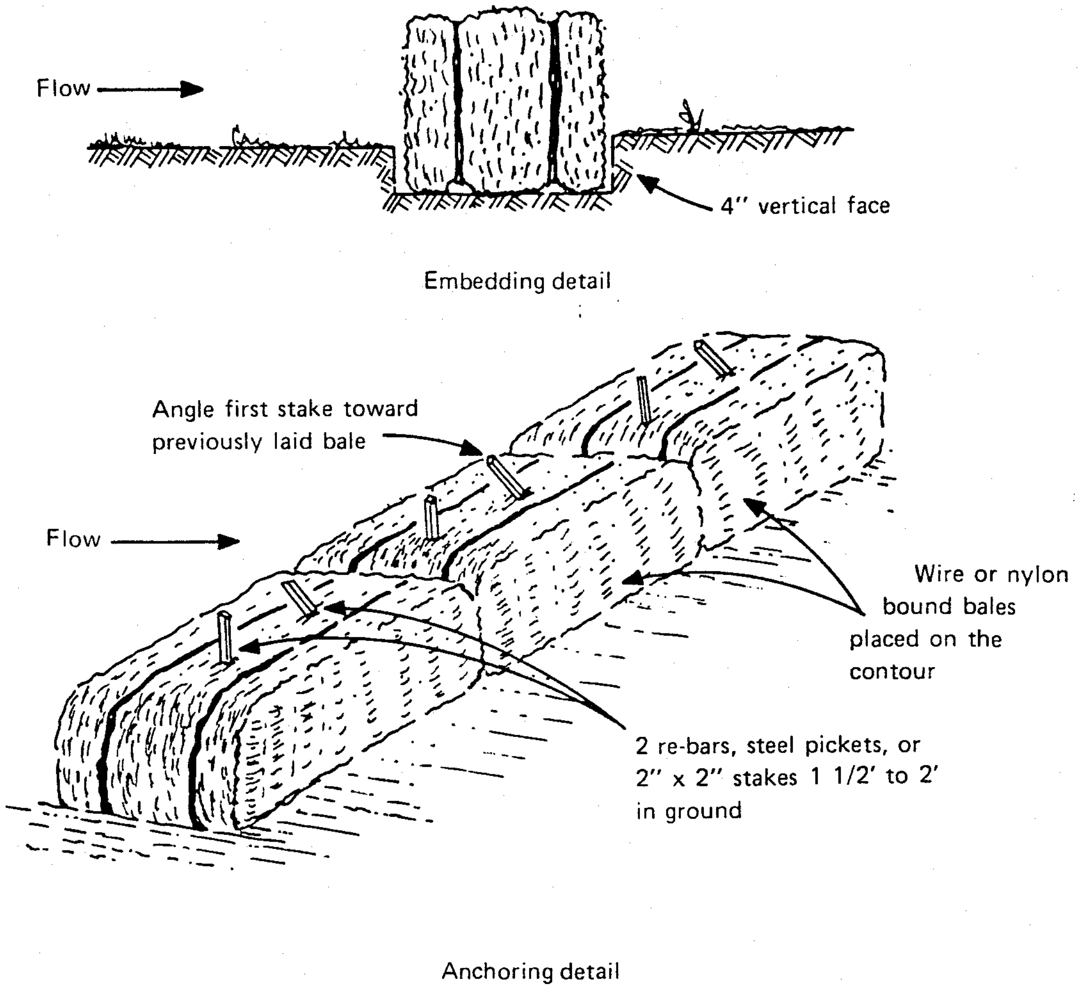


Figure 7-18. Typical straw-bale dike.

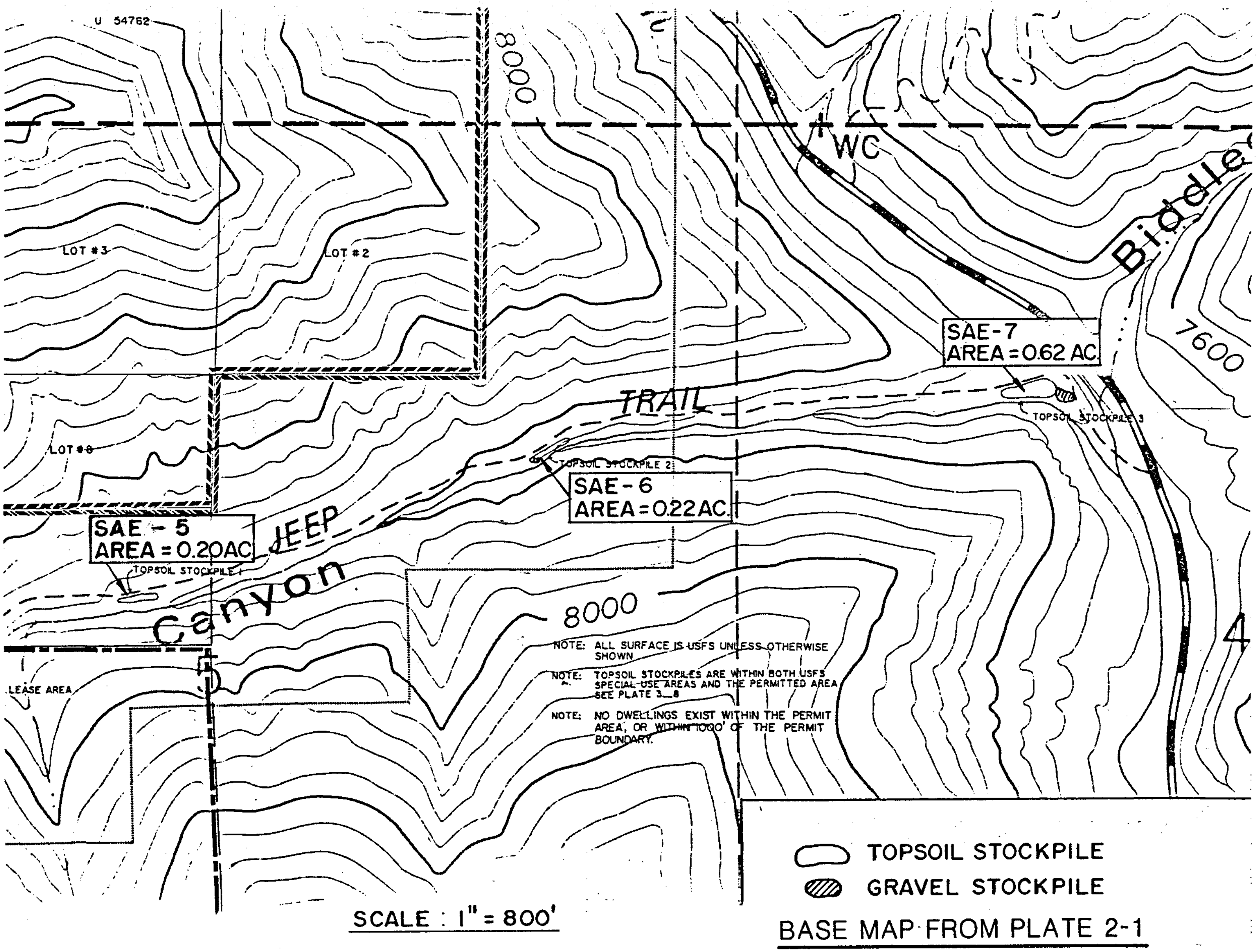


Figure 7-18a. Location of Topsoil and Gravel Stockpile Small Area Exemptions.

revegetation, a straw-bale dike was installed along the entire toe of SAE-1 to control sediment yields from the area prior to effective establishment of the vegetation. This has since been replaced with a silt fence in areas where the width of the revegetated section is less than 5 feet.

Calculations required to determine the effectiveness of the vegetation in controlling sediment yield from SAE-1 are contained in Appendix 7-9. According to these calculations, with the lower five feet of the reclaimed area acting as a grass filter, the peak suspended sediment concentration yielded by SAE-1 during the 10-year, 24-hour storm is 12 milligrams per liter. This value is less than the effluent concentration for total suspended solids required by UMC 817.42.

SAE-2 (consisting of 0.34 acre) exists at the northwest corner of the site. This area was initially constructed as a substation pad and associated access road. Because the substation has not been installed and may not be installed in the future, SAE-2 will be reclaimed. Of the total area, 0.15 acre received final reclamation treatment and 0.19 acre received contemporaneous reclamation treatment (see Section 3.5 and Plate 7-5). An additional area of 0.90 acre of undisturbed area drains onto SAE-2 from above.

Site drainage could be constructed to cause this area to drain to the sedimentation pond. However, enlargement of the pond to accept runoff from this area would be feasible only if a culvert was installed in Crandall Creek. The resulting damage to Crandall Creek (i.e., removal of riparian vegetation, alteration of the channel cross section, etc.) for the sole purpose of sediment control is not considered justifiable.

SAE-2 was reclaimed (contemporaneous and final) as outlined in Section 3.5. A sediment trap was installed at the downstream end of this area to control sediment yield. This trap utilizes the maximum space available and has a surface area of 150 square feet (10 feet by 15 feet). A 12-inch CMP culvert was installed to act as a spillway. This culvert discharges into UD-1. Details of the design of the sediment trap are contained in Appendix 7-9.

The effectiveness of the sediment trap was modeled using SEDIMOT II. Results of these analyses are contained in Appendix 7-9. According to this information, the peak effluent concentration of suspended sediment from the trap will be 2898 milligrams per liter. Although this concentration is greater than the standard contained in UMC 817.42, it is significantly less than the influent suspended sediment concentration from the undisturbed area that drains to the trap (17,320 milligrams per liter). Thus the net effect is to decrease suspended sediment concentrations from the area below that which would naturally occur.

As an option for further reducing effluent sediment concentrations, the possibility of adding silt fences to the sediment trap was examined. Adding silt fences to act as baffles within the trap (thus increasing the flow path and decreasing the dead space in the trap) did not significantly reduce the peak effluent concentration. Adding silt-fence material to the inlet of the outflow culvert would increase detention time in the trap but would significantly reduce the hydraulic effectiveness of the spillway, thus increasing the potential for overtopping of the trap and subsequent downstream erosion. Thus, the sediment trap as designed was considered to be the best option for control of SAE-2.

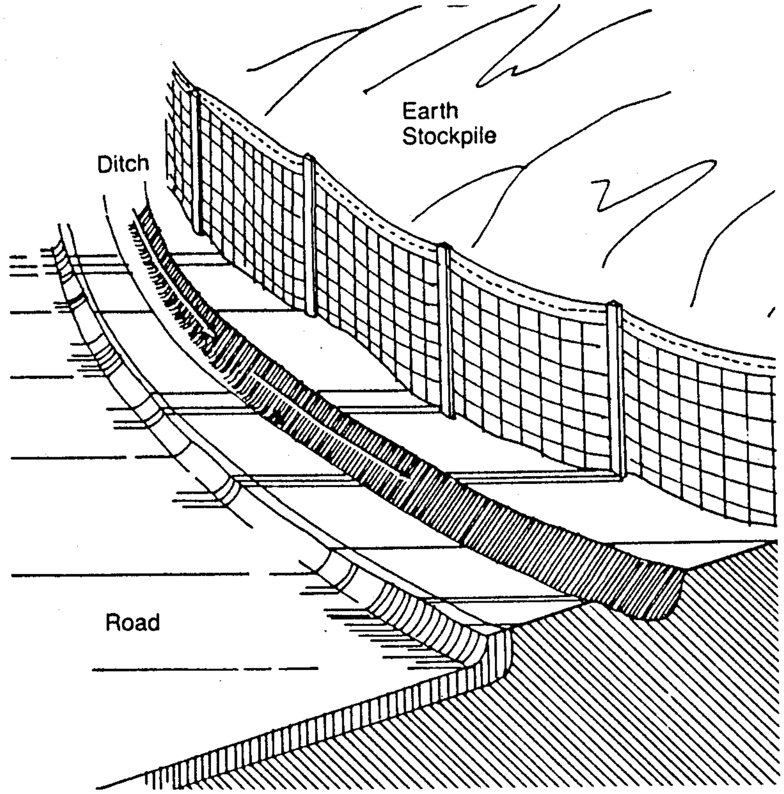
SAE-3 consists of a small area (0.32 acre) on the south side of the U.S. Forest Service access road that has served in the past as the materials storage/office pad. The northern portion of this area was reclaimed using final reclamation techniques outlined in Section 3.5 (see Plate 7-5). A berm of boulders was placed between SAE-3 and the road to prevent access to the reclaimed area. A straw-bale dike (Figure 7-18) was installed along the southern portion of the reclaimed area to serve as a sediment-control device prior to effective revegetation.

The southern portion of SAE-3 consists of boulders piled against the outslope of the pad. These boulders were blasted from the site high wall during initial construction. Due to potential stability problems that might be created by removal and the difficulty of removing these boulders from the outslope, this slope will remain unreclaimed.

The effectiveness of the reclamation activities was modeled using SEDIMOT II. Results of these calculations are contained in Appendix 7-9. According to this appendix, the peak effluent suspended sediment concentration from SAE-3 during the 10-year, 24-hour storm is 2 milligrams per liter. This concentration is within the standards established by UMC 817.42.

SAE-4 consists of a 0.14-acre area on the outslope (south side) of the U.S. Forest Service road between SAE-1 and SAE-3. Periodic grading and maintenance of the access road results in fresh soil occasionally being deposited on the outslope, limiting the potential for the outslopes to the contemporaeously reclaimed. Thus, because the area does not report to the sedimentation pond, alternate sediment control will be provided.

Sedimentation control in SAE-4 will be provided by installing a silt fence along the entire length of the toe of the road outslope. The silt fence will be installed in accordance with Figure 7-18b. The silt fence will be periodically inspected



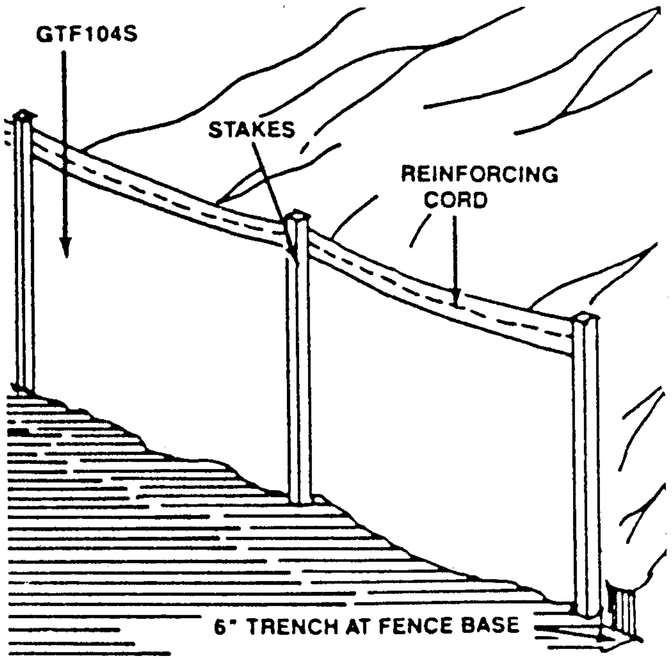


Figure 7-18b. Typical silt fence installation.

and repaired as required to ensure that its integrity is maintained.

SAE-5, SAE-6, and SAE-7 consist of the topsoil stockpiles that are located on the south side of the access road east of the mine site in the areas indicated in Figure 7-18a. SAE-6 and SAE-7 also include small gravel stockpiles used for maintenance of the access road. Disturbed areas associated with the topsoil/ gravel small-area exemptions are 0.20 acre, 0.22 acre, and 0.62 acre for SAE-5, SAE-6, and SAE-7, respectively.

Sedimentation control for SAE-5, SAE-6, and SAE-7 will be provided by installing straw-bale dikes around the perimeter of each disturbed area. These dikes will be installed in accordance with Figure 7-18. The dikes will be periodically inspected and repaired as required to ensure that their integrity is maintained.

A diversion (UD-1) was placed along the western edge of the site at the location shown on Plate 7-5 to divert water from a 95-acre undisturbed watershed around the yard area. Analyses and design information associated with this and other diversions associated with the site are contained in Appendix 7-7.

The diversion was designed to safely pass the peak flow from the 25-year, 24-hour precipitation event. The resulting peak flow from this event (as noted in Appendix 7-7) was determined to be 47.7 cubic feet per second. This diversion is designed as a 42-inch full-round CMP. The diversion discharges onto natural boulders and water (during high flow of Crandall Creek) after passing beneath the U.S. Forest Service road to aid in energy dissipation. Details of the design are contained in Appendix 7-7.

Two additional diversions were designed to convey water from undisturbed areas away from the disturbed site. One (UD-2) was constructed in the northwest portion of the site along the proposed substation pad. The other was constructed in the northeastern portion of the site to convey water away from the portal area. Details of diversion design are presented in Appendix 7-7. Both of these diversions were designed to safely pass the peak flow resulting from the 25-year, 24-hour storm.

Existing and proposed culverts in the mine yard were examined to determine their adequacy with respect to passing the peak flow from the 10-year, 24-hour precipitation event. Details of these designs are provided in Appendix 7-7.

Similarly, ditches within the disturbed area were designed to pass the peak flow from the 10-year, 24-hour storm. Typical cross sections and design calculations are contained in Appendix 7-7 for these ditches.

A berm was placed around the proposed power substation to prevent runoff water that accumulates thereon from flowing across the remainder of the site. A small channel on the substation pad collects water from the pad and adjacent undisturbed areas. A stilling basin was placed at the downstream end of this diversion to trap sediment prior to discharging into UD-1 (see Appendix 7-7).

Plate 7-5a shows as-built surface runoff controls. Cross sections noted on Plate 7-5a are shown on Plate 7-5b. Appendix 7-11 contains as-built calculations for diversions and culverts. Watershed boundaries used in the as-built calculations for diversions and culverts are shown on Plate 7-5c.

7.2.4 EFFECTS OF MINING ON SURFACE WATER

Runoff- and sediment-control facilities have been designed for the permit area surface facilities in accordance with applicable DOGM regulations. Facilities for the permit area were designed to safely convey and control runoff from the specified design storm events. Thus, sediment yields due to mining operations in the permit area will be minimized by the appropriate facilities.

The existing sedimentation pond has been reconstructed during the 1986 construction season in accordance with UMC 817.46, as detailed in the Runoff and Sediment control Plan located in Chapter 7.

Underground sumps will be built in order to effectively treat underground water before discharging into Crandall Creek, refer to Plate 3-7 for sump location. These sumps will be designed and submitted to the EPA for approval before discharge begins. All discharge into the creek will meet effluent limitations of the NPDES permit and monitored in accordance with same, refer to Item 3-8.

The sediment pond and the underground sumps are the only water treatment facilities proposed at the mine site. A NPDES permit has been issued for the sediment pond and is included as Item 3-8.

Water is intermittently discharged from the permit area into Crandall Creek. Since this water is treated in the pond by settling prior to discharge, impacts to the quality of surface water in the area are minimized.

Genwal has historically pumped a maximum of 12,000 gallons per day from Crandall Creek for underground use when in-mine quantities are insufficient to support underground operations. Assuming a 240-day work year, this quantity equals 8.8 acre-feet per year. Genwal agrees to maintain minimum instream flows in Crandall Creek as discussed in Section 7.2.3.1.

Water required for dust suppression on the haul road is also used at a rate of approximately 12,000 gallons per day. During the 120-day watering season, a watering usage of 4.4 acre-feet is possible. If sufficient water is available underground this water is obained from the mine. Otherwise, dust suppression water is obtained from Crandall Creek. Hence, total potential usage of water from Crandall Creek results in the diversion of about 13.2 acre-feet per year from Crandall Creek. This quantity represents approximately 0.5 percent of the average annual flow of the stream. This percentage is considered insignificant. Shares in the Huntington-Cleveland Irrigation Company have been purchased to cover the usage of this water.

7.2.5 MITIGATION AND CONTROL PLANS

As indicated, runoff- and sediment-control facilities have been designed for the permit area to protect the surface hydrologic balance of the area and mitigate potential impacts. These facilities will be inspected quarterly in the future to ensure adequate functioning during operation of the additional lease area (U 054762). Required repairs will be implemented immediately. A typical form to be used during inspection is provided in Figure 7-19.

GENWAL COAL COMPANY

DAM SAFETY INSPECTION REPORT

DAM NAME: ______________________________

HAZARD RATING: __________ COUNTY: __________ FOREST: __________

INSPECTOR'S SIGNATURE: ________________________ DATE: ______

Government personnel at Inspection: __________________________
____
____

Owner's Representative at Inspection: ________________________
____
____

Storage Level at Time of Inspection: _________________________

Outflow: Outlet: ________________ Spillway: ________________

Weather: ____

Note: A [No] in the Not Applicable column means not observed due to current field conditions.

EMBANKMENT	Not Applicable	No Problem	Minor Problem	Needs Repair	Critical
Meets Design	[ ]	[ ]	[ ]	[ ]	[ ]
Settling	[ ]	[ ]	[ ]	[ ]	[ ]
Slumps/Sloughing	[ ]	[ ]	[ ]	[ ]	[ ]
Cracking	[ ]	[ ]	[ ]	[ ]	[ ]
Erosion	[ ]	[ ]	[ ]	[ ]	[ ]
Seepage	[ ]	[ ]	[ ]	[ ]	[ ]
Drains	[ ]	[ ]	[ ]	[ ]	[ ]
Riprap	[ ]	[ ]	[ ]	[ ]	[ ]
Vegetation	[ ]	[ ]	[ ]	[ ]	[ ]
Rodents	[ ]	[ ]	[ ]	[ ]	[ ]
Debris	[ ]	[ ]	[ ]	[ ]	[ ]

Comments and Photographs: ____________________________________
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Figure 7-19. Typical sedimentation pond inspection form.

DAM NAME: ______________________________ PAGE 2

ABUTMENTS AND FOUNDATION	Not Applicable	No Problem	Minor Problem	Needs Repair	Critical
Settling	[ ]	[ ]	[ ]	[ ]	[ ]
Cracking	[ ]	[ ]	[ ]	[ ]	[ ]
Slumps	[ ]	[ ]	[ ]	[ ]	[ ]
Bulging	[ ]	[ ]	[ ]	[ ]	[ ]
Seepage	[ ]	[ ]	[ ]	[ ]	[ ]
Ponding	[ ]	[ ]	[ ]	[ ]	[ ]
Sinkholes	[ ]	[ ]	[ ]	[ ]	[ ]
Erosion	[ ]	[ ]	[ ]	[ ]	[ ]
Vegetation	[ ]	[ ]	[ ]	[ ]	[ ]

Comments and Photographs: ______________________________

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SPILLWAY	Not Applicable	No Problem	Minor Problem	Needs Repair	Critical
Meets Design	[ ]	[ ]	[ ]	[ ]	[ ]
Freeboard	[ ]	[ ]	[ ]	[ ]	[ ]
Control Operation	[ ]	[ ]	[ ]	[ ]	[ ]
Leekage					
From Spillway	[ ]	[ ]	[ ]	[ ]	[ ]
Into Spillway	[ ]	[ ]	[ ]	[ ]	[ ]
Erosion	[ ]	[ ]	[ ]	[ ]	[ ]
Siltation	[ ]	[ ]	[ ]	[ ]	[ ]
Debris	[ ]	[ ]	[ ]	[ ]	[ ]
Vegetation	[ ]	[ ]	[ ]	[ ]	[ ]
Outfall Channel	[ ]	[ ]	[ ]	[ ]	[ ]
Concrete Structure					
Settlement	[ ]	[ ]	[ ]	[ ]	[ ]
Cracks & Spalls	[ ]	[ ]	[ ]	[ ]	[ ]
Waterstops	[ ]	[ ]	[ ]	[ ]	[ ]
Undercutting	[ ]	[ ]	[ ]	[ ]	[ ]
Weep Holes/Drains	[ ]	[ ]	[ ]	[ ]	[ ]

Comments and Photographs: ______________________________

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Figure 7-19. Continued

DAM NAME: ______________________________

RESERVOIR BASIN	Not Applicable	No Problem	Minor Problem	Needs Repair	Critical
Fractures	[ ]	[ ]	[ ]	[ ]	[ ]
Sinkholes	[ ]	[ ]	[ ]	[ ]	[ ]
Sedimentation	[ ]	[ ]	[ ]	[ ]	[ ]
Debris	[ ]	[ ]	[ ]	[ ]	[ ]
Vegetation	[ ]	[ ]	[ ]	[ ]	[ ]
Shore Stability	[ ]	[ ]	[ ]	[ ]	[ ]
Storage Gage	[ ]	[ ]	[ ]	[ ]	[ ]

Comments and Photographs: ______________________________

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OUTLET	Not Applicable	No Problem	Minor Problem	Needs Repair	Critical
Meets Design	[ ]	[ ]	[ ]	[ ]	[ ]
Controls					
Access w/ Spill	[ ]	[ ]	[ ]	[ ]	[ ]
Operation	[ ]	[ ]	[ ]	[ ]	[ ]
Measuring Device	[ ]	[ ]	[ ]	[ ]	[ ]
Intake					
Siltation	[ ]	[ ]	[ ]	[ ]	[ ]
Debris	[ ]	[ ]	[ ]	[ ]	[ ]
Trash Rack	[ ]	[ ]	[ ]	[ ]	[ ]
Conduit					
Displacement	[ ]	[ ]	[ ]	[ ]	[ ]
Deterioration	[ ]	[ ]	[ ]	[ ]	[ ]
Joints	[ ]	[ ]	[ ]	[ ]	[ ]
Blockage	[ ]	[ ]	[ ]	[ ]	[ ]
Leakage	[ ]	[ ]	[ ]	[ ]	[ ]
Camber	[ ]	[ ]	[ ]	[ ]	[ ]
Downstream Channel					
Pooling	[ ]	[ ]	[ ]	[ ]	[ ]
Backcutting	[ ]	[ ]	[ ]	[ ]	[ ]
Erosion	[ ]	[ ]	[ ]	[ ]	[ ]
Vegetation	[ ]	[ ]	[ ]	[ ]	[ ]
Debris	[ ]	[ ]	[ ]	[ ]	[ ]

Comments and Photographs: ______________________________

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Figure 7-19. Continued.

DAM NAME: ______________________ PAGE 4

SEEPAGE	location	gpm	sediment	comments
	1	[ ]	[ ]	[ ]
	2	[ ]	[ ]	[ ]
	3	[ ]	[ ]	[ ]
	4	[ ]	[ ]	[ ]

SLUMPS AND SINKHOLES	location	comments
	A	[ ]
	B	[ ]
	C	[ ]

OVERALL COMMENTS AND RECOMMENDATIONS

Figure 7-19. Continued.

DAM NAME: ______________________________ PAGE 5

SKETCH - Indicate North, downstream, seeps, leaks, sinkholes etc.

. + ... + ... + ... + ... + ... + ... + .

. + ... + ... + ... + ... + ... + ... + .

. + ... + ... + ... + ... + ... + ... + .

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Figure 7-19. Continued.

Impacts from mining to the quantity of water in the Crandall Creek watershed are expected to be minimal, as noted previously. If, alternative water supplies are required to replace existing surface water supplies, shares of the Huntington-Cleveland Irrigation Company owned by Genwal will be transfered for this purpose.

7.2.6 SURFACE WATER MONITORING PLAN

Two 36-inch Parshall flumes that were installed in July 1985 on Crandall Creek (one upstream from the surface facilities and one downstream; see Figure 7-20). These flumes are equipped with Stevens Type-F water-level recorders to allow the collection of continuous flow data. Charts will be changed and the flumes inspected on a monthly basis.

Water quality samples will be collected from the flume locations quarterly (normally in January, April, July, and October), and analyzed according to the list contained in Table 7-8. Every fifth year (1990, 1995, etc.), the samples collected during the low-flow period (normally October) will be analyzed according to Table 7-9. All samples will be analyzed for total and dissolved constituents according to the indicated lists. Discharges from the sedimentation pond will be analyzed in accordance with the NPDES permit for the facility.

Surface-water monitoring data will be submitted to DOGM on a quarterly basis. At the end of each calendar year, an annual summary will be submitted. This annual summary will analyze and describe variations in flows and quality during the year and will include tables, graphs, hydrographs, etc. as appropriate.

Due to the close proximity of the sedimentation pond to Crandall Creek, the piezometer installed in the dam (see Plate 7-4) will be monitored on a quarterly basis to reduce the likelihood of a potential dam failure.

Water-level measurements will be collected from the piezometer immediately prior to and following full-scale clean out of the sedimentation pond. If the pre- and post-cleaning water levels vary by less than 0.5 foot, monitoring following clean out will occur on a weekly basis for a period of one month. If significant changes are not noted during this one-month period (as determined in consultation with DOGM), the monitoring frequency will return to a quarterly interval. If significant water-level changes are noted during the post-clean out weekly monitoring period or if there is other evidence to indicate that the embankment is rapidly saturating, Genwal will notify DOGM within a 15-day period of the water-level changes and will mutually agree upon additional monitoring requirements.

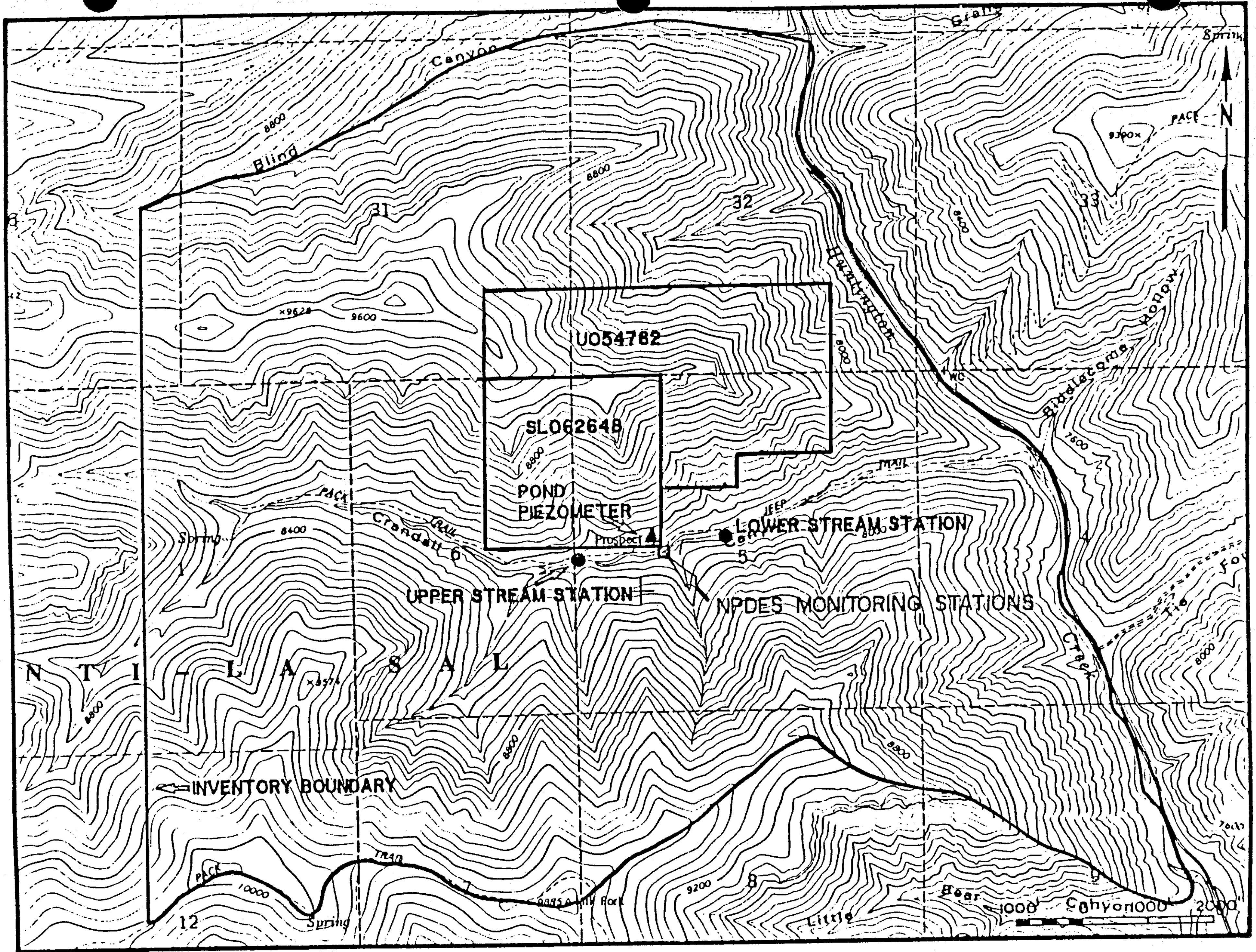

Figure 7-20. Location of Surface Water Monitoring Stations.

7-81

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Table 7-8. Abbreviated surface water analysis list.

Field Measurements:
Flow
pH
Specific conductance (umhos/cm)
Temperature (^{o}C)
Dissolved oxygen (ppm)
Laboratory Measurements:
Total dissolved solids
Total suspended solids
Total settleable solids
Total hardness (as $CaCO_3$)
Acidity (as $CaCO^3$)
Bicarbonate (as HCO_3)
Carbonate (as CO_3)
Calcium (as Ca)
Chloride (as Cl)
Dissolved iron (as Fe)
Total iron (as Fe)
Magnesium (as Mg)
Manganese (as Mn)
Potassium (as K)
Sodium (as Na)
Sulfate (as SO_4)
Oil and Grease
Cation - Anion balance

Table 7-9. Extended surface water analysis list.

Field Measurements:

Flow
pH
Specific conductance (umhos/cm)
Temperature (^oC)
Dissolved oxygen (ppm)

Laboratory Measurements:

Total dissolved solids
Total suspended solids
Total settleable solids
Total hardness (as $CaCO_3$)
Acidity (as $CaCO^3$)
Aluminum (as Al)
Arsenic (as As)
Barium (as Ba)
Bicarbonate (as HCO_3)
Boron (as B)
Carbonate (as CO_3)

Cadmium (as Cd)
Calcium (as Ca)
Chloride (as Cl)
Chromium (as Cr)
Copper (as Cu)
Fluoride (as F)
Dissolved iron (as F)
Total Iron (as Fe)
Lead (as Pb)
Magnesium (as Mg)
Manganese (as Mn)

Mercury (as Hg)
Molybdenum (as Mo)
Nickel (as Ni)
Nitrogen-Ammonia (as NH_3)
Nitrite (as NO_2)
Nitrate (as NO_3)
Potassium (as K)
Phosphate (as PO_4)
Selenium (as Se)
Sodium (as Na)

Sulfate (as SO_4)
Sulfide (as S)
Zinc (as Zn)
Oil and Grease
Cation - Anion balance

The slope-stability analysis presented in Appendix 7-6 assumed that the water level at the location of the piezometer (Section B-B') was at an elevation of 7764 feet (20 feet below the surface of the embankment at the piezometer). Under these conditions, the dam was shown to be stable. If the water level in the piezometer rises above this elevation, water will be immediately withdrawn from the pond. If available data indicate that the water in the pond meets the effluent limitations contained in UMC 817.42 and any applicable NPDES permits, this water will be pumped directly to Crandall Creek. Any direct discharges will be monitored at the beginning and end of pumping from the pond. The pump inlet will be placed on a floating ring to avoid pulling excess sediment into the discharge tube during pumping. Water will be pumped from below the water surface to avoid introduction of oil to the discharge water.

If the pond requires rapid dewatering and the quality of the water is such that it cannot be discharged directly to Crandall Creek, the water will be pumped into sumps contained in the underground workings. These sumps are constructed large enough to provide for storage of the surface water. Once the water in the underground sumps is of sufficient quality to meet the effluent limitations of UMC 817.42 and any applicable NPDES permits, the water will be discharged to Crandall Creek. Genwal is currently reviewing their existing NPDES permit to determine if a new or revised permit will be required to discharge water from the sedimentation pond to the underground workings and thence to the creek.

During the post-operational period, surface-water data will be collected from the upper and lower stations shown in Figure 7-20 and the inflow to the sedimentation pond as indicated on Plate 3-4. Flow data will be collected continuously from the flumes at the upper and lower Crandall Creek stations and twice annually (during the high- and low-flow seasons) from the sedimentation pond inflow during the post-mining period. In addition, water-quality samples will be collected from each station during the high- and low-flow seasons following mining. These samples will be analyzed for the parameters listed in Table 7-8. Data thus collected will be submitted to DOGM on a quarterly basis.

The post-mining reports will contain not only the laboratory and field data but also an assessment of current impacts from mining on surface-water systems and the amount of recovery of the system since mining. Surface-water monitoring following mining will continue until the termination of the bonding period.

7.3 ALLUVIAL VALLEY FLOOR DETERMINATION

The permit area is located only in upland areas of the Crandall Creek watershed containing a thin veneer of colluvial deposits. As a result, the area is not underlain by an alluvial valley floor.

The area occupied by the surface facilities (adjacent to Crandall Creek) is a steep, narrow canyon with only limited amounts of rocky alluvium. No agricultural activities have been conducted in the area in the past nor will they be in the future due to the limited width of alluvium along the stream (less than 10 feet) and to restrictive climatic conditions. Hence, the Crandall Creek area adjacent to the surface facilities is also not an alluvial valley floor. This conclusion is supported by the U.S. Soil Conservation Service (see Appendix 7-12).

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